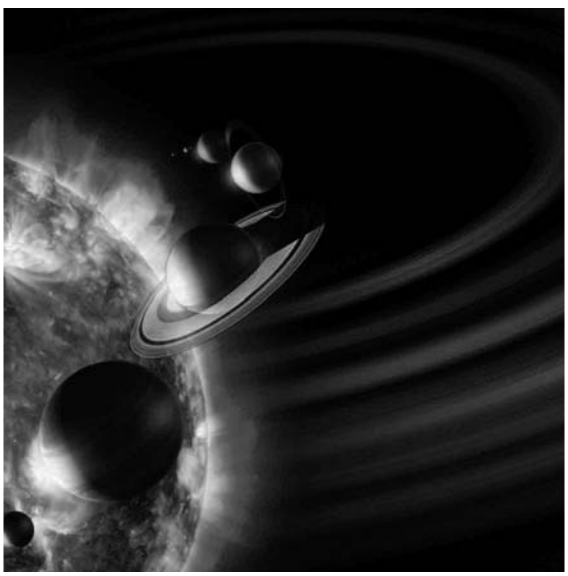
# PLANETARY SCIENCE

| Budget Authority (in $ millions) | Actual FY 2011 | Estimate FY 2012 | FY 2013 | Notional FY 2014 | FY 2015 | FY 2016 | FY 2017 |
|---|---|---|---|---|---|---|---|
| **FY 2013 President's Budget Request** | **1,450.8** | **1,501.4** | **1,192.3** | **1,133.7** | **1,102.0** | **1,119.4** | **1,198.8** |
| Planetary Science Research | 158.8 | 174.1 | **188.5** | 222.5 | 233.4 | 231.7 | 230.3 |
| Lunar Quest Program | 130.2 | 139.9 | **61.5** | 6.2 | 0.0 | 0.0 | 0.0 |
| Discovery | 192.0 | 172.6 | **189.6** | 242.2 | 235.6 | 193.8 | 134.3 |
| New Frontiers | 213.2 | 160.7 | **175.0** | 269.8 | 279.6 | 259.9 | 155.1 |
| Mars Exploration | 547.4 | 587.0 | **360.8** | 227.7 | 188.7 | 266.9 | 503.1 |
| Outer Planets | 91.9 | 122.1 | **84.0** | 80.8 | 78.8 | 76.2 | 76.3 |
| Technology | 117.3 | 144.9 | **132.9** | 84.6 | 85.9 | 90.9 | 99.6 |

# PLANETARY SCIENCE RESEARCH

## FY 2013 BUDGET

| | Actual | Estimate | | Notional | | | |
|---|---|---|---|---|---|---|---|
| **Budget Authority (in $ millions)** | **FY 2011** | **FY 2012** | **FY 2013** | **FY 2014** | **FY 2015** | **FY 2016** | **FY 2017** |
| **FY 2013 President's Budget Request** | **158.8** | **174.1** | **188.5** | **222.5** | **233.4** | **231.7** | **230.3** |
| Planetary Science Research and Analysis | 122.3 | 122.3 | **125.3** | 130.1 | 133.5 | 134.6 | 135.5 |
| Other Missions and Data Analysis | 24.0 | 27.4 | **38.8** | 64.6 | 72.1 | 69.5 | 66.9 |
| Education and Directorate Management | 4.6 | 4.0 | **4.0** | 7.3 | 7.3 | 7.1 | 7.4 |
| Near Earth Object Observations | 7.8 | 20.4 | **20.5** | 20.5 | 20.5 | 20.5 | 20.5 |
| Change From FY 2012 Estimate | -- | -- | **14.5** | | | | |
| Percent Change From FY 2012 Estimate | -- | -- | **8.3%** | | | | |



**So much NASA planetary science activity occurred between October 2010 and August 2012 that the Planetary Science Division refers to this period as the "Year of the Solar System," although it is a Martian year rather than an Earth year. It takes Mars about 23 Earth-months to orbit the Sun, and during the Year of the Solar System triple the usual number of launches, flybys and orbital insertions will occur. The Year of the Solar System concludes in August 2012 when Curiosity lands on Mars. The roving nuclear-powered science laboratory is expected to open a new chapter in exploration of the Red Planet.**

The Planetary Science Research program develops analytical and theoretical tools as well as laboratory data needed to support flight missions data analysis. The program also initiates development of new and better instrument ideas that will potentially fly on future missions. These capabilities allow Planetary Science to answer specific questions about, and increase the understanding of, the origin and evolution of the solar system. The program represents an essential complement to planetary flight missions, providing the scientific research and the theoretical foundation to allow the Nation to plan and fully use the unique data sets returned from the missions exploring the solar system. It is also NASA’s primary interface with university faculty and graduate students in this field, and the research community in general. The research program achieves this by supporting research grants solicited annually and subjected to a careful peer review before selection and award. The content of the program includes mission supporting Research and Analysis (R&A), Other Missions and Data Analysis, and the Near Earth Object Observation program (NEOO).

# PLANETARY SCIENCE RESEARCH

## EXPLANATION OF MAJOR CHANGES FOR FY 2013

The Joint Robotics Program for Exploration project has been added to the program. This project will support the integration of Exploration and Planetary science efforts, including jointly funding instruments on planetary spacecraft. The funding increase in research and analysis enables NASA to select an increased number of highly rated peer reviewed proposals for maximum scientific benefits.

## ACHIEVEMENTS IN FY 2011

NEOO achieved greater than 90-percent completeness for documenting the population of one kilometer and larger objects, and continued efforts for finding and characterizing smaller asteroids approaching Earth that may be destinations and resources for our exploration of the solar system and ones that could become potential impact hazards to the Earth. Competitive announcements were released soliciting R&A proposals and the Research program continued to curate and distribute solar system samples (astromaterials) returned by NASA planetary missions such as Stardust, Genesis, and Hayabusa. The program also provided continued support for the Rosetta mission's arrival at comet Churyumov-Gerasimenko in January 2014.

## KEY ACHIEVEMENTS PLANNED FOR FY 2013

In pursuit of fundamental science that guides planetary exploration, the Planetary Science Research program will continue to select highly rated R&A proposals that support Planetary missions and goals. Planetary science will continue to archive and distribute relevant mission data to the science community and the public in a timely manner. The Planetary Science Research Program is archiving data from all of Planetary's active missions. In addition to digital data, many scientists funded within the R&A program will be allocated samples of asteroid Itokawa, collected by the Hayabusa mission run by JAXA. The first samples were delivered to NASA in late 2011, and will be available for research in spring 2012. Proposed research includes studies of space weathering on asteroids, critical for planning future missions to asteroids, and the search for organic matter among samples relevant to future Exploration activities. Support will also continue for the Rosetta mission, as well as NEOO and JRPA.

## BUDGET EXPLANATION

The FY 2013 request is $188.5 million. This represents a $14.5 million increase from the FY 2012 estimate ($174.1 million).

Most of the increase is a result of adding the new project JRPA ($10 million) to the program for the benefit of supporting the integration of Science and Exploration future missions and goals. Additional funding increases were made to Planetary R&A to accommodate more proposals and Rosetta for preparations for the selection of science observations, software tools, and operations risk reduction.

# PLANETARY SCIENCE RESEARCH

## Non-Operating Missions

### RESEARCH AND ANALYSIS

The scope of Planetary's mission supporting R&A is very broad, addressing NASA goals and providing the foundation for the formulation of new scientific questions and strategies for accomplishing those goals. R&A will provide new theories and instrumentation concepts that will enable the next generation of flight missions. Discoveries and concepts developed in the R&A project aid in the genesis of scientific priorities, missions, instrumentation, and investigations. R&A supports research tasks in areas such as: astrobiology and cosmochemistry; the origins and evolution of planetary systems; and the atmospheres, geology, and chemistry of the solar system's planets, other than Earth. R&A provides for instrument and measurement concepts, and supports the initial definition of mission concepts and development of instruments for future Discovery, New Frontiers, Mars, or outer planets missions.

### EDUCATION AND DIRECTORATE MANAGEMENT

The Robotics Alliance Project (RAP) is dedicated to increasing interest in STEM disciplines among youth in the U.S. Annual activities and events expose students to challenging applications of engineering and science. RAP supports national robotic competitions in which high school students team with engineers from government, industry, and universities to gain hands-on experience and mentoring from engineering and technical professionals.

The Directorate Management project supports SMD-wide administrative and programmatic requirements.

### NEAR EARTH OBJECT OBSERVATIONS (NEOO)

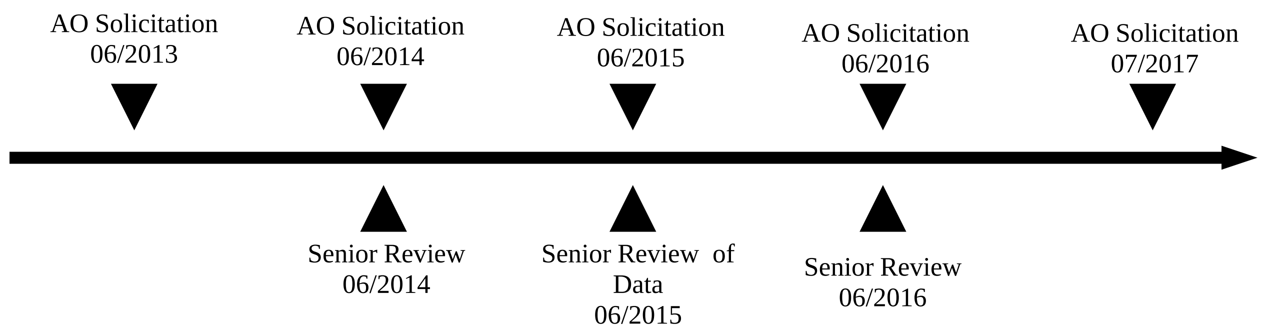
The NEOO project detects and tracks at least 90 percent of the near Earth objects (NEOs), asteroids and comets that come within 1.3 astronomical units of the Sun. It finds those as small as 140 meters in size and that have any potential to collide with Earth and do significant damage to the planet. Planetary objects that could be viable targets for robotic and crewed exploration will also be discovered and initially characterized where possible.

In FY 2011, NASA, in accordance with the findings and recommendations of the January 2010 National Academies study on the NEO hazard, continued to: collect, archive, and analyze the small body data collected by NASA's WISE mission, and supported increased follow-up and analysis of this data; enabled collection of NEO detection and characterization data by the USAF Panoramic Survey Telescope and Rapid Reporting System (Pan-STARRS) and investigated the use of other USAF space surveillance assets for this mission; supported the continued operation of planetary radar capabilities at the NSF's Arecibo and NASA's Goldstone facilities; and finally, investigated both ground and space-based concepts for increasing capacity to detect, track and characterize potentially hazardous objects down to sizes of 140 meters and below. These efforts will continue in 2013.

For more information on NEOO, visit the Web site at: http://neo.jpl.nasa.gov.

# PLANETARY SCIENCE RESEARCH

## Program Schedule




## Program Management & Commitments

| Project/Element | Provider |
|---|---|
| R&A | Provider: NASA<br>Project Management: HQ<br>NASA Center: ARC, GRC, GSFC, JPL, JSC, LaRC, MSFC, HQ<br>Cost Share: N/A |
| NEOO | Provider: NASA<br>Project Management: HQ<br>NASA Center: HQ, GSFC, JPL, ARC<br>Cost Share: NSF, USAF, Smithsonian Astrophysical Observatory (SAO) |

## Acquisition Strategy

The R&A budget will fund competitively selected activities from the ROSES omnibus research announcement. NEOO data processing nodes are located at the Minor Planet Center (Cambridge, MA) and the Sentry high precision orbit determination node at JPL.

# PLANETARY SCIENCE RESEARCH

## INDEPENDENT REVIEWS

| Review Type | Performer | Last Review | Purpose/Outcome | Next Review |
|---|---|---|---|---|
| Quality | Planetary Science Subcommittee | 2011 | Review to assess goals and objectives of program; recommendation was to maintain a strong program consistent with the decadal survey recommendation | TBD |

# OTHER MISSIONS AND DATA ANALYSIS

| Formulation | Development | Operations |
|---|---|---|

## FY 2013 BUDGET

| Budget Authority (in $ millions) | Actual FY 2011 | Estimate FY 2012 | FY 2013 | Notional FY 2014 | FY 2015 | FY 2016 | FY 2017 |
|---|---|---|---|---|---|---|---|
| **FY 2013 President's Budget Request** | **24.0** | **27.4** | **28.8** | **54.6** | **62.1** | **59.5** | **56.9** |
| Joint Robotics Program for Exploration | 0.0 | 0.0 | **10.0** | 10.0 | 10.0 | 10.0 | 10.0 |
| Planetary Science Directed R&T | 0.0 | 0.0 | **0.0** | 19.4 | 30.3 | 32.8 | 37.3 |
| Planetary Data System | 11.5 | 13.6 | **13.3** | 13.7 | 13.8 | 13.8 | 13.8 |
| Astromaterial Curation | 5.5 | 5.8 | **4.9** | 5.0 | 5.1 | 5.2 | 5.3 |
| Rosetta | 6.3 | 8.0 | **10.6** | 16.5 | 12.8 | 7.6 | 0.5 |
| Change From FY 2012 Estimate | -- | -- | **1.4** | | | | |
| Percent Change From FY 2012 Estimate | -- | -- | **5.1%** | | | | |

**Visible on this 17-pound Antarctic meteorite is a dark fusion crust of melted material, created during high-speed entry through Earth's atmosphere. JSC curators have sent 17,000 meteorite samples to more than 500 scientists worldwide.**

The Other Missions and Data Analysis portion of the Research program includes supporting mission functions such as the Planetary Data Systems and the Astromaterials Curation as well as supporting the NASA portion of the ESA Rosetta mission.

# Non-Operating Missions

## JOINT ROBOTICS PROGRAM FOR EXPLORATION

Beginning in FY 2013, the Planetary Science Division, working closely with the HEOMD, will invest in a joint robotics precursor activity that will develop instruments relevant to human exploration beyond low Earth orbit, and fund a research and analysis effort with the goal of turning the data gathered by these instruments, as well as the data of other SMD instruments and missions, into strategic knowledge in support of human spaceflight planning and systems development. Many of these research and analyses activities will be jointly conducted with HEOMD to maximize the mutual benefit to both science and exploration objectives, as was done with the highly successful LRO mission.

# OTHER MISSIONS AND DATA ANALYSIS

| Formulation | Development | Operations |
| --- | --- | --- |

## PLANETARY SCIENCE DIRECTED RESEARCH AND TECHNOLOGY

This project funds the civil service staff that will work on emerging Planetary Science flight projects, instruments and research. The workforce and funding will transfer to projects by the beginning of FY 2013.

## PLANETARY DATA SYSTEMS

Planetary Data Systems facilitates achievement of NASA's planetary science goals by efficiently collecting, archiving, and making accessible digital data produced by, or relevant to, NASA's planetary missions, research programs, and data analysis. It is the active data archive for NASA's Planetary Science theme. The archives include data products derived from a wide range of measurements, including imaging experiments, magnetic and gravity field measurements, orbit data, and various spectroscopic observations. The Planetary Data Systems archives make available space-borne, ground-based, and laboratory experiments from over 50 years of NASA-funded exploration of comets, asteroids, moons, and planets.

## ASTROMATERIAL CURATION

The Astromaterials Curation Facility at JSC is responsible for the curation of all extraterrestrial material under NASA control. Curation is an integral part of any sample return mission. It comprises initial characterization of new samples, preparation and allocation of samples for research and education, and provides a clean and secure storage for the benefit of current and future generations. Samples currently include Apollo lunar samples, Antarctic meteorites, solar wind, comet and interplanetary dust particles, soil, and rocks.

# Flight Operating Missions

## ROSETTA

Rosetta, an ESA/NASA comet rendezvous mission in operations phase that launched in March 2004, will arrive at comet Churyumov-Gerasimenko in FY 2014. Rosetta will enable study of the nature and origin of comets, the relationship between cometary and interstellar material, and the implications of comets with regard to the origin of the solar system. The Rosetta spacecraft will be the first to undertake the long-term exploration of a comet at close quarters. It comprises a large orbiter, which is designed to operate for a decade at large distances from the Sun, and a small lander. Each of these elements carries a large number of scientific experiments and examinations designed to complete the most detailed study of a comet ever attempted. Rosetta will allow scientists to look back 4,600 million years to a time when no planets existed and only a vast swarm of asteroids and comets surrounded the Sun.

## Recent Achievements

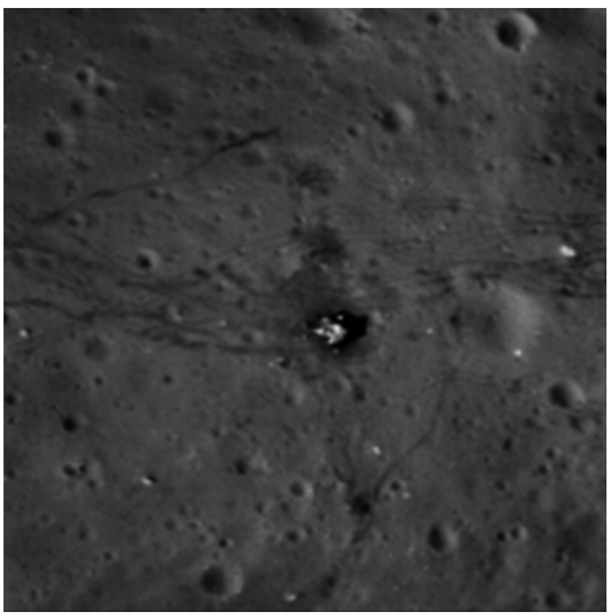
### ROSETTA

Rosetta has completed all of its pre-hibernation activities and has begun its science planning phase while the spacecraft prepares for its approach to comet Churyumov-Gerasimenko currently scheduled for 2014. The spacecraft will remain in hibernation as it continues toward the comet.

# LUNAR QUEST

## FY 2013 BUDGET

| Budget Authority (in $ millions) | Actual FY 2011 | Estimate FY 2012 | FY 2013 | Notional FY 2014 | FY 2015 | FY 2016 | FY 2017 |
|---|---|---|---|---|---|---|---|
| **FY 2013 President's Budget Request** | **130.2** | **139.9** | **61.5** | **6.2** | **0.0** | **0.0** | **0.0** |
| Lunar Science | 61.7 | 66.7 | **17.3** | 3.7 | 0.0 | 0.0 | 0.0 |
| Lunar Atmosphere and Dust Environment Explorer | 64.5 | 70.4 | **41.4** | 2.5 | 0.0 | 0.0 | 0.0 |
| Surface Science Lander Technology | 4.0 | 2.8 | **2.8** | 0.0 | 0.0 | 0.0 | 0.0 |
| Change From FY 2012 Estimate | -- | -- | **-78.4** | | | | |
| Percent Change From FY 2012 Estimate | -- | -- | **-56.0%** | | | | |



**An LRO Narrow Angle Camera image shows the Apollo 17 landing site. This final mission of the Apollo program (December 1972) returned the richest collection of lunar materials from any lunar site.**

Lunar Quest conducts scientific exploration of the Moon through research and analysis and through the development of small-to-medium satellite and possibly surface missions. Lunar Quest addresses the science priorities identified in the National Academies report, "The Scientific Context for Exploration of the Moon." Lunar Quest complements other lunar missions sponsored by NASA and international agencies.

Projects included are the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission, Lunar Reconnaissance Orbiter (LRO) mission, Lunar Management, and Lunar Science Research. These projects address Lunar Quest objectives, which include providing opportunities to conduct lunar-focused science missions and research; re-establishing lunar science and a lunar science community; and facilitation of new technologies to support flight missions.

## EXPLANATION OF MAJOR CHANGES FOR FY 2013

Consistent with the priorities of the 2011 National Academies decadal survey for Planetary Science, Lunar Quest will end shortly after the LADEE mission completion, currently scheduled for FY 2014. The remaining ongoing science will be absorbed within the Discovery program.

# LUNAR QUEST

## ACHIEVEMENTS IN FY 2011

Striking new lunar images and maps have been added to the already comprehensive collection of raw lunar data and high-level products, including mosaic images, which LRO has made possible. The spacecraft's seven instruments delivered more than 192 terabytes of data with an unprecedented level of detail. This comprehensive data set will provide a deeper understanding of the Moon and its environment and be used to support the extension of human presence in the solar system. Sites will be identified that are close to potential resources and have high scientific value, favorable terrain, and the environment necessary for safe future robotic and human lunar missions.

The Surface Science Lander Technology project conducted its second free-flight test of a robotic Lander prototype on June 16, 2011. During test, the Lander successfully executed its planned flight profile, autonomously ascending to a six-foot hover and descending to conduct a controlled soft landing.

## KEY ACHIEVEMENTS PLANNED FOR FY 2013

LADEE Operational Readiness and Flight Readiness Reviews are currently scheduled for September 2013.

## BUDGET EXPLANATION

The FY 2013 request is $61.5 million. This represents a $78.4 million decrease from the FY 2012 estimate ($139.9 million).

# Non-Operating Missions

## SURFACE SCIENCE LANDER TECHNOLOGY

The Surface Science Lander Technology project was established to create a new generation of small, smart, versatile robotic landers that will achieve scientific and exploration goals on the surface of the moon and other airless planetary bodies, including near-Earth asteroids. The lander capability being developed will pave the way for many exciting robotic scientific missions. NASA's Robotic Lander Test Bed conducts test activities to prove the design of this new generation of robotic landers. MSFC and the Johns Hopkins University Applied Physics Laboratory (JHU-APL) engineers are currently conducting studies and test activities to aid in the design of this new generation of multi-use landers for future robotic space exploration.

In 2013, the project will continue to test and develop its robotic lander technology that will be capable of performing science and exploration research at multiple destinations in the solar system. The technology will provide a means to test sensors, avionics, software, landing legs, and integrated system elements to support autonomous landings on airless planetary bodies in the solar system.

# LUNAR QUEST

## LUNAR SCIENCE RESEARCH

The Lunar Science Research project was established to enhance participation and collaboration within the lunar science community. It is composed of competed research and analysis opportunities that include: the NASA Lunar Science Institute (NLSI), a virtual institute of geographically dispersed researchers and institutions, directed by ARC for management and implementation; the Lunar Advanced Science and Exploration Research program, a lunar-only element in the annual ROSES competitive research announcement; and Lunar Data, which supports lunar data archives and distribution to the science community.

## LUNAR MANAGEMENT

Lunar Management provides management and oversight of selected flight missions
reviews.

## LUNAR RECONNAISSANCE ORBITER

The primary objective of the HEOMD LRO mission was to conduct investigations that prepare for future human lunar exploration. Specifically LRO scouted for safe and compelling landing sites, located potential resources (with special attention to the possibility of water ice) and characterized the effect of prolonged exposure to the lunar radiation environment. Final delivery of LRO exploration data to the Planetary Data System occurred on March 15, 2011, fully satisfying the ESMD's mission requirements.

Following completion of its mission for HEOMD, LRO was transferred into the Science Mission Directorate in September 2010, and NASA adjusted its operations to focus on rich scientific data that will help us to better understand the moon's topography and composition. LRO is now devoting the capabilities of the seven LRO instruments to five science investigations: the bombardment history of the Moon; the lunar geologic processes and their role in the evolution of the crust and lithosphere; the processes that have shaped the global lunar regolith; the types, sources, sinks, and transfer mechanisms associated with volatiles on the Moon; and how the space environment interacts with the lunar surface, in order to advance our understanding of the origin and evolution of the Moon.

In FY 2012, LRO will complete its primary science mission operations (completing the data analysis in FY 2013). NASA will consider extending LRO science operations for an additional two years as part of a Senior Review of operating Planetary Science missions.

# Program Schedule

The Lunar Quest program will end shortly after the LADEE mission completion, currently scheduled for FY 2014.

# LUNAR QUEST

## Program Management & Commitments

MSFC has program management responsibility for the Lunar Quest program, providing overall mission management oversight.

| Project/Element | Provider |
|---|---|
| LRO | Provider: GSFC<br>Project Management: GSFC<br>NASA Center: JSC, JPL, JHU-APL<br>Cost Share: N/A |
| Surface Science Lander | Provider: MSFC<br>Project Management: MSFC<br>NASA Center: MSFC, JHU-APL<br>Cost Share: N/A |
| Lunar Science | Provider: HQ<br>Project Management: HQ<br>NASA Center: ARC, GSFC, MSFC, JPL, JSC<br>Cost Share: N/A |

## Acquisition Strategy

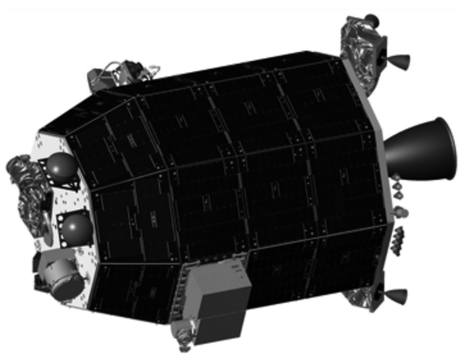
All major procurements are in place. No new awards are expected in FY 2013.

# LUNAR ATMOSPHERE & DUST ENVIRONMENT EXPLORER (LADEE)

| Formulation | Development | Operations |
|---|---|---|

## FY 2013 BUDGET

| Budget Authority (in $ millions) | Prior | Actual FY 2011 | Estimate FY 2012 | FY 2013 | FY 2014 | FY 2015 | FY 2016 | FY 2017 | BTC | LCC Total |
|---|---|---|---|---|---|---|---|---|---|---|
| **FY 2013 President's Budget Request** | **84.1** | **64.5** | **70.4** | **41.4** | **2.5** | **0.0** | **0.0** | **0.0** | **0.0** | **262.9** |
| **2012 MPAR Project Cost Estimate** | **84.1** | **64.5** | **70.4** | **41.4** | **2.5** | **0.0** | **0.0** | **0.0** | **0.0** | **262.9** |
| Formulation | 79.5 | -- | -- | -- | -- | -- | -- | -- | -- | 79.5 |
| Development/ Implementation | 4.7 | 64.5 | 70.4 | 36.2 | -- | -- | -- | -- | -- | 175.8 |
| Operations | -- | -- | -- | 5.2 | 2.5 | -- | -- | -- | -- | 7.7 |
| Change From FY 2012 Estimate | | -- | -- | **-29.0** | | | | | | |
| Percent Change From FY 2012 Estimate | | -- | -- | **-41.2%** | | | | | | |



**The National Academies report *The Scientific Context for Exploration of the Moon* lists studies of the pristine state of the lunar atmosphere and dust environment as two of eight major priorities for future lunar science missions. LADEE was developed to address these two priorities.**

## EXPLANATION OF MAJOR CHANGES FOR FY 2013

Calendar year 2013 is the year of transition from development to operations. The increase of $7.6 million in development reflects current detailed phasing plans for this transition.

## PROJECT PURPOSE

The purpose of LADEE is to determine the global density, composition, and time variability of the lunar atmosphere. LADEE's measurements will determine the size, charge, and spatial distribution of electrostatically transported dust grains. Additionally, LADEE will carry an optical laser communications demonstrator that will test high-bandwidth communication from lunar orbit. LADEE will measure lunar dust and examine the lunar atmosphere. In addition, it will broaden the scientific understanding of other planetary bodies regarding exospheres or very thin atmospheres, like the moon.

# LUNAR ATMOSPHERE & DUST ENVIRONMENT EXPLORER (LADEE)

| Formulation | Development | Operations |
|---|---|---|

## PROJECT PARAMETERS

LADEE will deliver its science using three instrument packages: the Neutral Mass Spectrometer (NMS), the Ultra Violet Spectrometer (UVS), and Lunar Dust EXperiment (LDEX). The mission will be testing a new first-of-its-kind spacecraft architecture called the "Modular Common Bus," developed by NASA as a flexible, low cost, rapid turn-around spacecraft for both orbiting and landing on the Moon and other deep space targets. It is hoped that such a capability will enable the Agency to perform future science goals for reduced cost.

In addition to three science instruments, LADEE will carry the Lunar Laser Communications Demonstration (LLCD) sponsored by HEOMD to demonstrate high-bandwidth optical communications for the first time from lunar orbit. LADEE will be launched on a Minotaur V, procured by the Air Force, from NASA's Wallops Flight Facility (WFF). LADEE is an in-house development project, the first spacecraft to be built internally at ARC.

## ACHIEVEMENTS IN FY 2011

LADEE completed its Critical Design Review on May 20, 2011.

## KEY ACHIEVEMENTS PLANNED FOR FY 2013

LADEE is scheduled to complete all integration and testing and be delivered to the WFF launchpad in FY 2013.

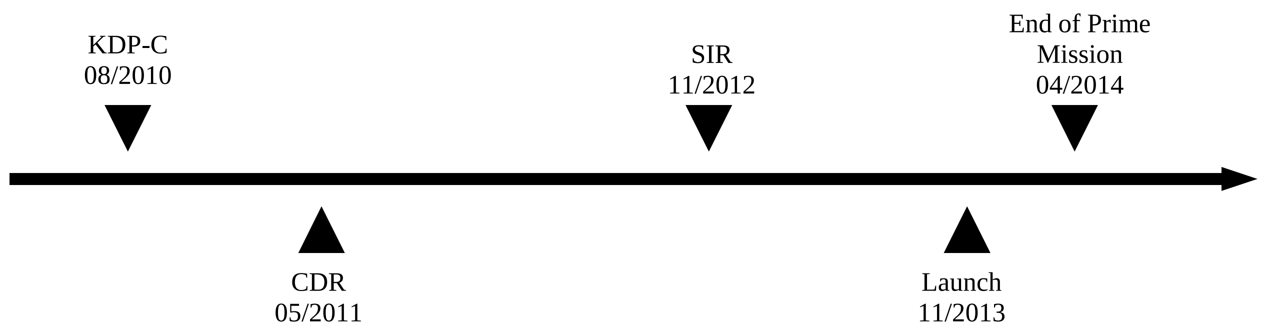
## SCHEDULE COMMITMENTS/KEY MILESTONES

| Development Milestones | Confirmation Baseline Date | FY 2013 PB Request Date |
|---|---|---|
| KDP-C | Aug-10 | Aug-10 |
| CDR | May-11 | May-11 |
| SIR | Nov-12 | Nov-12 |
| Launch | Nov-13 | Nov-13 |
| End of Prime Mission | Apr-14 | Mar-14 |

# LUNAR ATMOSPHERE & DUST ENVIRONMENT EXPLORER (LADEE)

| Formulation | Development | Operations |
| --- | --- | --- |

## Project Schedule




## Development Cost and Schedule

| Base Year | Base Year Development Cost Estimate ($M) | JCL (%) | Current Year | Current Year Development Cost Estimate ($M) | Cost Change (%) | Key Milestone | Base Year Milestone Date | Current Year Milestone Date | Milestone Change (months) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2011 | 168.2 | 70 | 2012 | 175.8 | 4.5 | LRD | Nov-13 | Nov-13 | 0 |

Note: *The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. The estimate above reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as joint confidence level; all other confidence levels reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

# LUNAR ATMOSPHERE & DUST ENVIRONMENT EXPLORER (LADEE)

| Formulation | Development | Operations |
|---|---|---|

## DEVELOPMENT COST DETAILS (IN $M)

| Element | Base Year Development Cost Estimate | Current Year Development Cost Estimate | Change from Base Year Estimate |
|---|---|---|---|
| **TOTAL:** | **168.2** | **175.8** | **7.6** |
| Aircraft/Spacecraft | 34.8 | 36.7 | 1.9 |
| Payloads | 15 | 16.0 | 1.0 |
| Systems I&T | 6.7 | 8.9 | 2.2 |
| Launch Vehicle | 45.7 | 47.0 | 1.3 |
| Ground Systems | 3.5 | 5.6 | 2.1 |
| Science/Technology | 0.8 | 1.2 | 0.4 |
| Other Direct Project Costs | 61.7 | 60.5 | -1.2 |

# LUNAR ATMOSPHERE & DUST ENVIRONMENT EXPLORER (LADEE)

| Formulation | Development | Operations |
|---|---|---|

## Project Management & Commitments

LADEE operates under the Lunar Quest program of the SMD Planetary Science Division. The decision authority is the SMD Associate Administrator. ARC has day-to-day overall management.

| Project Element | Provider | Description | FY 2012 PB | FY 2013 PB |
|---|---|---|---|---|
| Spacecraft | Provider: ARC<br>Project Management: ARC<br>NASA Center: ARC<br>Cost Share: N/A | Design, build and deliver the spacecraft | Same | Same |
| Neutral mass Spectrometer (NMS) Instrument | Provider: GSFC<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | Design, build and deliver the NMS instrument. Also responsible for integrating of LDEX and UVS | Same | Same |
| UV Spectrometer (UVS) Instrument | Provider: ARC<br>Project Management: ARC<br>NASA Center: ARC<br>Cost Share: N/A | Design, build and deliver. | Same | Same |
| Lunar Dust EXperiment (LDEX) Instrument | Provider: Univ of Colorado, LASP<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | Design, build and deliver. | Same | Same |
| Launch Vehicle | Provider: USAF<br>Project Management: AF<br>NASA Center: WFF<br>Cost Share: N/A | Integrate vehicle and provide launch service | Nomenclature of rocket (from IV+ to V) | Same |

# LUNAR ATMOSPHERE & DUST ENVIRONMENT EXPLORER (LADEE)

| Formulation | Development | Operations |
|---|---|---|

## Project Risks

| Risk Statement | Mitigation |
|---|---|
| If: LLCD Optical Module delivery is late,<br>Then: the delay will impact the LADEE launch readiness date. | The LLCD team adjusted the testing sequence and ARC adjusted their I&T flow, to ensure meeting the need dates |

## Acquisition Strategy

All major acquisitions are in place. The spacecraft bus was directed to ARC and will provide the Ultra Violet Spectrometer in partnership with GSFC who will provide the Neutral Mass Spectrometer. The Lunar Dust Experiment was competitively selected through stand alone missions of opportunity notices and awarded to the University of Colorado LASP. The USAF Orbital/Suborbital program and Orbital Sciences Corporation are providing the launch vehicle.

### INDEPENDENT REVIEWS

| Review Type | Performer | Last Review | Purpose/Outcome | Next Review |
|---|---|---|---|---|
| SIR | SRB | Nov-11 | The purpose is to evaluate the readiness of the overall system to commence integration and test, to review the verification and validation plans, integration plans, and test plans, and to ensure test articles (hardware/software), test facilities, support personnel, and test procedures are ready for testing and data acquisition, reduction, and control. The outcome resulted in a requirement to conduct Internal Readiness Reviews prior to radiator panel integration and structure assembly and test, and a delta SIR prior to Observatory integration.. | late spring 2012 |

# DISCOVERY

## FY 2013 BUDGET

| Budget Authority (in $ millions) | Actual FY 2011 | Estimate FY 2012 | FY 2013 | Notional FY 2014 | FY 2015 | FY 2016 | FY 2017 |
|---|---|---|---|---|---|---|---|
| **FY 2013 President's Budget Request** | **192.0** | **172.6** | **189.6** | **242.2** | **235.6** | **193.8** | **134.3** |
| Change From FY 2012 Estimate | -- | -- | **16.9** | | | | |
| Percent Change From FY 2012 Estimate | -- | -- | **9.8%** | | | | |

**All completed Discovery missions have achieved ground-breaking science, each taking a unique approach to space exploration, doing what's never been done before, and driving new technology innovations.**

NASA's Discovery program provides scientists the opportunity to dig deep into their imaginations and find innovative ways to unlock the mysteries of the solar system. When it began in 1992, this program represented a breakthrough in the way NASA explores space. For the first time, scientists and engineers were called on to assemble teams and design exciting, focused planetary science investigations that would deepen our knowledge about our solar system.

The Discovery program goal is to achieve outstanding results by launching many smaller missions using fewer resources and shorter development times. The main objective is to enhance our understanding of the solar system by maximizing the different missions to explore the planets, their moons, and small bodies such as comets and asteroids. The program also seeks to improve performance through the use of new technological achievements.

The scientific requirements of solar system exploration have driven some of the most remarkable engineering achievements of the past five decades. For example, prior to the Dawn mission, only chemical propulsion had been used on all previous planetary missions. A major step forward in interplanetary transportation technology occurred in 2001 with the successful flight of Deep Space 1, powered by solar electric, or ion, propulsion. This technology can reduce the propellant required to reach certain planetary destinations by a factor of 10 or more. Dawn is the first planetary science mission to use solar electric propulsion (demonstrated by Deep Space 1) which will allow it to orbit two asteroids on one trip through space.

# DISCOVERY

## EXPLANATION OF MAJOR CHANGES FOR FY 2013

As a result of the planned phase out of the Lunar Quest program, the Discovery program is absorbing ongoing lunar science activities. The FY 2013 President's Budget Request supports the launch of a Discovery 12 mission within the advertised 24 month window.

## ACHIEVEMENTS IN FY 2011

Exciting accomplishments during 2011 include the Stardust NExT encounter of Tempel 1, DAWN orbiting the asteroid Vesta, and the GRAIL launch. On February 14, 2011, the Stardust spacecraft flew past the nucleus of comet Tempel 1 to provide images of the crater left by the Deep Impact mission on this same comet in July 2005. The spacecraft also produced images of new territory on the comet that had not been seen before.

DAWN entered orbit around Vesta, the second most massive object in the asteroid belt between Mars and Jupiter, in July 2011 and will remain there for about a year, lowering the orbit altitude in steps to collect more detailed data and images. The spacecraft will then use its ion thrusters to leave Vesta orbit in mid-2012 and begin its journey to Ceres, the largest asteroid in the belt.

GRAIL launched successfully from Cape Canaveral Air Force Station, FL, on September 10, 2011 and began a three-and-a-half-month journey to the Moon. GRAIL will create a gravity map of the Moon using two spacecraft that orbit in tandem and make very precise measurements of the changes in their separation distance caused by the Moon's gravity field. NASA solicited the help of U.S. students to provide names for the twin spacecraft, previously called GRAIL-A and GRAIL-B. The naming contest was open through November 2011 to students in kindergarten through 12th grade. The new names recently selected are Ebb and Flow.

In addition, the Discovery program has selected three new and exciting concepts studies and will down-select to one in the summer of 2012. All previously completed Discovery missions have achieved ground-breaking science, each taking a unique approach to space exploration, doing what's never been done before, and driving new technology innovations that may also improve life on Earth. In support of NASA's education program goals, the Discovery program helps communicating the excitement and meaning of space exploration to students and the public. The program has offered workshops to educators across the country, interactive websites for the public, exhibits, special events, newsletters, and other forms of communication.

For more information on the Discovery program, please see http://discovery.nasa.gov/index.html.

## KEY ACHIEVEMENTS PLANNED FOR FY 2013

The GRAIL mission will complete its collection of gravity data for the Moon. The selected Discovery 12 mission will enter the Preliminary Design Phase.

# DISCOVERY

## BUDGET EXPLANATION

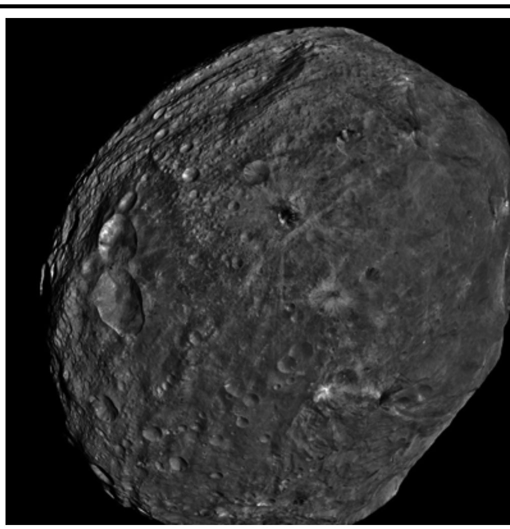
The FY 2013 request is $189.6 million. This represents a $16.9 million increase from the FY 2012 estimate ($172.6 million).

Though some project's budgets, such as GRAIL, DAWN, and MESSENGER, will be reduced as they continue into their Operations phase, the overall increase in the Discovery program is a result of beginning the execution of the Discovery 12 mission selection.

# OTHER MISSIONS AND DATA ANALYSIS

## FY 2013 BUDGET

| | Actual | Estimate | | Notional | | | |
|---|---|---|---|---|---|---|---|
| **Budget Authority (in $ millions)** | **FY 2011** | **FY 2012** | **FY 2013** | **FY 2014** | **FY 2015** | **FY 2016** | **FY 2017** |
| **FY 2013 President's Budget Request** | **192.0** | **172.6** | **189.6** | **242.2** | **235.6** | **193.8** | **134.3** |
| Discovery Research | 17.4 | 17.5 | **16.9** | 15.9 | 16.1 | 16.3 | 16.3 |
| Discovery Future Missions | 4.5 | 60.7 | **138.3** | 197.4 | 195.5 | 163.9 | 96.2 |
| Discovery Management | 7.5 | 9.0 | **11.3** | 11.8 | 12.1 | 12.4 | 12.5 |
| Strofio | 6.2 | 1.6 | **0.9** | 1.3 | 0.7 | 0.8 | 0.8 |
| GRAIL | 103.4 | 29.8 | **8.7** | 0.0 | 0.0 | 0.0 | 0.0 |
| Dawn | 14.8 | 14.3 | **8.1** | 10.1 | 11.3 | 0.4 | 8.5 |
| MESSENGER | 22.7 | 34.9 | **4.6** | 5.0 | 0.0 | 0.0 | 0.0 |
| ASPERA-3 | 0.9 | 0.9 | **0.8** | 0.6 | 0.0 | 0.0 | 0.0 |
| Deep Impact | 5.3 | 4.0 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 |
| Stardust | 7.8 | 0.0 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 |
| Moon Mineralogy Mapper | 1.6 | 0.0 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 |
| Change From FY 2012 Estimate | -- | -- | **16.9** | | | | |
| Percent Change From FY 2012 Estimate | -- | -- | **9.8%** | | | | |



**Dawn mission data has revealed the rugged topography and complex textures of the asteroid Vesta's surface. Soon other pieces of data such as the chemical composition, interior structure, and geologic age will help scientists understand the history of this remnant protoplanet and its place in the early solar system. After a year orbiting Vesta, the Dawn spacecraft will depart in July 2012 for the dwarf planet Ceres, where it will arrive in 2015.**

Other Missions and Data Analysis funds all Discovery activities, except for major missions being readied for launch. It includes missions of opportunity (e.g. Strofio and ASPERA-3) with lifecycle costs to NASA of less than $35 million; operating missions (GRAIL, Dawn, MESSENGER); missions whose operations have ceased (Deep Impact, Stardust, Moon Mineralogy Mapper); competed research; funding for future mission selections; and management activities.

# Non-Operating Missions

## DISCOVERY RESEARCH

Discovery Research includes funding for: the Discovery Data Analysis program, analyzing archived data from Discovery missions; Laboratory Analysis of Returned Samples which is building new instruments for use in terrestrial laboratories, to analyze samples returned from NASA Planetary Science missions; and participating scientists for the MESSENGER, Dawn and GRAIL missions. Data access through Discovery Research allows broader science community analysis of the data and samples, and also allows research to continue for many years after a mission has been completed. Research proposals are made by scientists in the U.S. planetary community and are competitively selected through peer review.

### DISCOVERY FUTURE MISSIONS

Discovery Future Missions provides funds for future Discovery flight missions to be selected via a competitive Announcement of Opportunity process. Three concept studies are currently underway as a result of the Discovery 12 Announcement of Opportunity. Final selection of one mission is planned for June 2012.

### DISCOVERY MANAGEMENT

Discovery Program Management provides for the management oversight of flight missions selected for the program. It also supports the mission selection process, through the development of Announcements of Opportunity and the establishment of independent panel reviews to evaluate mission proposals.

## Operating Missions

### STROFIO

Strofio (Exospheric Sample of Mercury's Surface Composition) is the U.S. contribution of an instrument to the European Space Agency's BepiColombo mission, scheduled for launch in 2014. Strofio will provide valuable information about Mercury's exosphere and its interaction with the magnetosphere and surface.

### GRAVITY RECOVERY AND INTERIOR LABORATORY (GRAIL)

GRAIL is composed of two functionally identical spacecraft (called Ebb and Flow) that fly in tandem around the Moon to precisely measure and map variations in the Moon's gravitational field. The mission will provide the most accurate global gravity field to date for any planet, including Earth. This detailed information will reveal differences in the density of the Moon's crust and mantle and will help answer fundamental questions about the Moon's internal structure, thermal evolution, and history of collisions with asteroids. Launched in September 2011, GRAIL will complete its prime mapping operations in 2012. FY 2013 funding will be used to analyze the data collected during mission operations in FY 2012.

### DAWN

The Dawn mission is on a journey to the two oldest and most massive space rocks in the asteroid belt between Mars and Jupiter, Vesta and Ceres. Their surfaces are believed to contain a snapshot of the conditions present in the solar system's first 10 million years, allowing Dawn to investigate both the

# OTHER MISSIONS AND DATA ANALYSIS

origin and the current state of the solar system. By observing asteroid Vesta and dwarf planet Ceres with the same set of instruments, Dawn has the unique ability to compare and contrast them and answer questions about the formation and evolution of the early solar system. Launched in September 2007, Dawn reached Vesta in July 2011, and will arrive at Ceres in February 2015.

### MERCURY SURFACE, SPACE ENVIRONMENT, GEOCHEMISTRY, AND RANGING (MESSENGER)

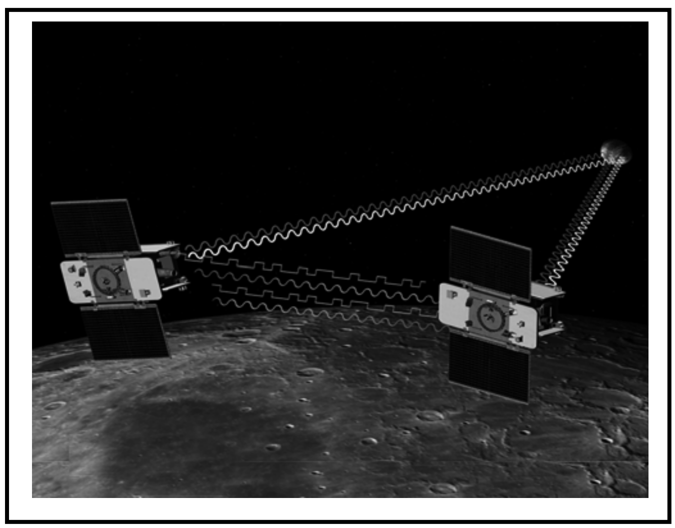
The MESSENGER mission is a scientific investigation of the planet Mercury, the smallest and least explored of the terrestrial planets. It is the only planet besides Earth to possess a global magnetic field. Understanding Mercury and the forces that have shaped it is fundamental to understanding the origin and evolution of the four rocky inner planets in our solar system. Launched in August 2004, MESSENGER entered Mercury orbit in March 2011 for a one year prime mission. The excellent science return and health of the spacecraft allowed approval of a one year mission operations extension to March 2013.

### ANALYZER OF SPACE PLASMA AND ENERGETIC ATOMS (ASPERA-3)

ASPERA-3 is one of seven scientific instruments aboard the European Space Agency's Mars Express spacecraft launched in June 2003 that are performing remote sensing measurements designed to answer questions about the Martian atmosphere, structure, and geology. ASPERA-3 is measuring ions, electrons, and energetic neutral atoms in the outer atmosphere to reveal the number of oxygen and hydrogen atoms (the constituents of water) interacting with the solar wind and the regions where such interaction occurs. Mars Express is now on its second mission extension.

## Recent Achievements

### GRAIL

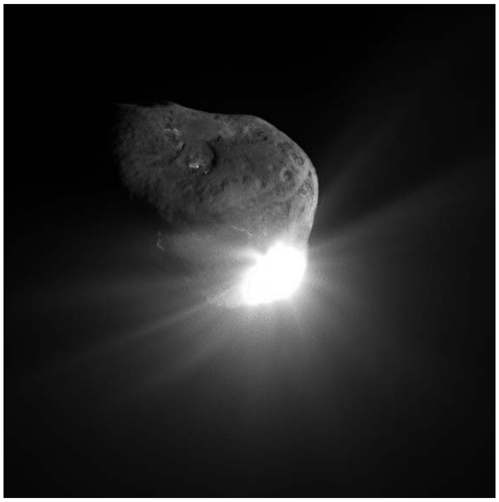


The twin GRAIL spacecraft successfully launched on September 10, 2011. Successful orbit insertion occurred on December 31, 2011, and January 1, 2012. The mission will begin its operations phase by mapping the moon's gravity with a precision formulation-flying technique. The end of the primary mission is scheduled for June 2012.

### DAWN

The spacecraft entered its year-long orbital mission around Vesta in July 2011, becoming the first spacecraft to orbit an object in the main asteroid belt.

# OTHER MISSIONS AND DATA ANALYSIS

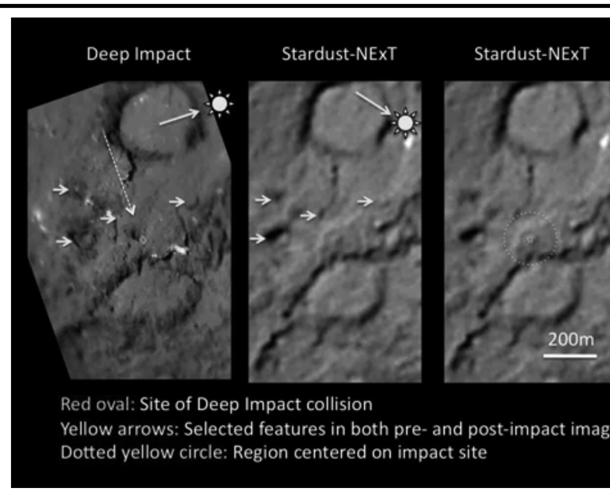


## DEEP IMPACT

The Deep Impact project successfully completed its repurposed science missions, referred to as EPOXI. EPOXI was comprised of two components; Extrasolar Planet Observations and Characterization (EPOCh) and the Deep Impact Extended Investigation (DIXI). The spacecraft reached the comet Hartley 2 in November 4, 2010. The data gathered from the Hartley 2 flyby will be compared to the data gathered from Tempel 1 and used for determining which cometary features represent primordial differences and which result from subsequent evolutionary processes.

## STARDUST

Stardust-NExT (Stardust-New Exploration of Tempel) completed its flyby of comet Tempel 1 on February 14, 2011. The data gathered was used to detect if any changes have occurred since the flyby of July 2005 by the Deep Impact mission. Scientists are still analyzing the disturbance to the surface on comet Tempel 1 where the Deep Impact collision occurred.



# NEW FRONTIERS

## FY 2013 BUDGET

| Budget Authority (in $ millions) | Actual FY 2011 | Estimate FY 2012 | FY 2013 | Notional FY 2014 | FY 2015 | FY 2016 | FY 2017 |
|---|---|---|---|---|---|---|---|
| **FY 2013 President's Budget Request** | **213.2** | **160.7** | **175.0** | **269.8** | **279.6** | **259.9** | **155.1** |
| OSIRIS-Rex | 4.9 | 110.3 | **137.5** | 228.8 | 224.2 | 202.1 | 44.9 |
| Other Missions and Data Analysis | 208.3 | 50.5 | **37.5** | 41.0 | 55.4 | 57.8 | 110.1 |
| Change From FY 2012 Estimate | -- | -- | **14.3** | | | | |
| Percent Change From FY 2012 Estimate | -- | -- | **8.9%** | | | | |

**The New Frontiers program seeks to contain total mission cost and development time and improve performance through the use of validated new technologies, efficient management, and control of design, development and operations costs while maintaining a strong commitment to flight safety. The program objective is to launch high-science-return planetary science investigations twice per decade.**

The New Frontiers program constitutes a critical element of NASA's solar system exploration capability that will perform high-quality focused scientific investigations. Initiated in 2003, the New Frontiers program was defined to pursue high-quality planetary missions that require resources beyond those available in the Discovery program. Unlike the Discovery program, the choice of destinations and the science goals for each New Frontiers opportunity are limited to the National Academies recommended science targets. These include: Venus In Situ Explorer, Saturn Probe, Trojan Tour and Rendezvous, the Comet Surface Sample Return, and Lunar South Pole-Aitken Basin Sample Return.

New Horizons is the first peer-review selected mission of the New Frontiers program and is currently on its way to its primary target, Pluto. It will conduct reconnaissance of Pluto and its moons Charon, Nixa, and Hydra. The dwarf planet Pluto has been revealed to be a multi-object system of small and large moons, never before seen up close. This mission will tell us a lot about how the Kuiper belt orbits form and their role in the early formation of the solar system.

# NEW FRONTIERS

## EXPLANATION OF MAJOR CHANGES FOR FY 2013

The third New Frontiers down-selection of one mission to proceed to the subsequent phases occurred as planned in late CY 2011. This project, OSIRIS-REx, entered its formulation phase in FY 2012 as planned.

## ACHIEVEMENTS IN FY 2011

Juno, the second New Frontiers mission with an overarching scientific goal to understand the origin and evolution of Jupiter and planetary formation, launched on August 5, 2011. OSIRIS-REx, the third New Frontiers mission, was selected in May 2011.

## KEY ACHIEVEMENTS PLANNED FOR FY 2013

In March 2013, OSIRIS-REx will complete its Preliminary Design Review (PDR) and proceed to design and development phase (phases C and D).

New Horizons will conduct and complete two instrumentation status checks during its cruise to Pluto.

Juno will use a gravity assist speed boost from Earth via an Earth flyby in October 2013.

For more information on the New Frontiers program, see http://newfrontiers.nasa.gov/index.html.

## BUDGET EXPLANATION

The FY 2013 request is $175.0 million. This represents a $14.3 million increase from the FY 2012 estimate ($160.7 million).

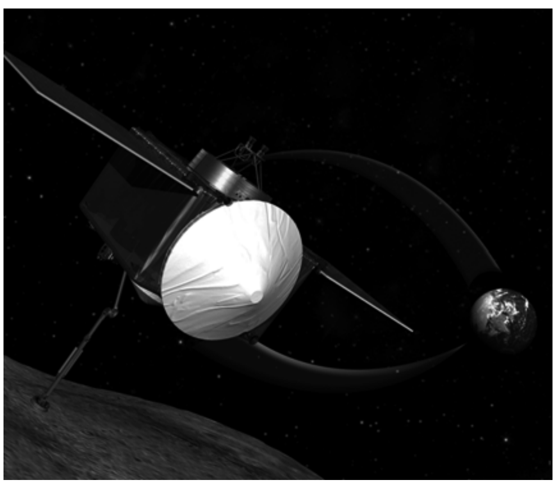
The project workforce on OSIRIS-REx is increasing, in preparation for launch in 2016.

# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER (OSIRIS-REX)

| Formulation | Development | Operations |
|---|---|---|

## FY 2013 BUDGET

| Budget Authority (in $ millions) | Prior | Actual FY 2011 | Estimate FY 2012 | FY 2013 | FY 2014 | FY 2015 | FY 2016 | FY 2017 | BTC | LCC Total |
|---|---|---|---|---|---|---|---|---|---|---|
| **FY 2013 President's Budget Request** | **0.0** | **4.9** | **110.3** | **137.5** | **228.8** | **224.2** | **202.1** | **44.9** | **0.0** | **952.7** |
| Change From FY 2012 Estimate | | -- | -- | **27.2** | | | | | | |
| Percent Change From FY 2012 Estimate | | -- | -- | **24.7%** | | | | | | |



**Asteroids are leftovers formed from the cloud of gas and dust, the solar nebula, that collapsed to form the Sun and the planets about 4.5 billion years ago. As such, they contain the original material from the solar nebula, which can tell scientists about the conditions of the solar system's birth. In sampling the near Earth asteroid designated 1999 RQ36 in 2019, OSIRIS-REx will be opening a time capsule from the birth of the solar system.**

## PROJECT PURPOSE

Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx) tentatively planned to launch in 2016

OSIRIS-REx will perform the following:

- Return and analyze a sample of pristine asteroid soil in an amount sufficient to study the nature, history, and distribution of its constituent minerals and organic material;
- Map the global properties, chemistry, and mineralogy of a primitive carbonaceous asteroid to characterize its geologic and dynamic history and provide context for the returned samples;
- Document the texture, morphology, volatile chemistry, and spectral properties of the regolith at the sampling site at scales down to the sub-millimeter;

# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER (OSIRIS-REX)

| Formulation | Development | Operations |
|---|---|---|

- Accurately measure the "Yarkovsky effect" on a potentially hazardous asteroid and constrain the asteroid properties that contribute to this effect; and
- Characterize the integrated global properties of a primitive carbonaceous asteroid to allow for direct comparison with ground-based telescopic data of the entire asteroid population.

The Yarkovsky effect is a small push caused by the Sun on an asteroid, as it absorbs sunlight and re-emits that energy as heat. The small push adds up over time, but it is uneven due to an asteroid's shape, wobble, surface composition and rotation. For scientists to predict an Earth-approaching asteroid's path, they must understand how the effect will change its orbit. OSIRIS-REx will study the orbit of asteroid RQ36 to ascertain its trajectory and devise future strategies to mitigate possible Earth impacts from celestial objects.

## EXPLANATION OF PROJECT CHANGES

None

## PROJECT PRELIMINARY PARAMETERS

OSIRIS-REx will tentatively launch in September 2016, encountering the target asteroid in October 2019. The mission will study the asteroid for up to 505 days, globally mapping the surface from distances of 5 kilometers to 0.7 kilometers. The spacecraft cameras and instruments will photograph the asteroid and measure its surface topography, composition, and thermal emissions. Radio science will provide mass and gravity field maps. This information will help the mission team select the most promising sample site, from which it will collect and return to Earth at least 60 grams of pristine material from asteroid RQ36. The sample return will use a capsule similar to that which returned the samples of comet 81P/Wild on the Stardust spacecraft, allowing the sample to return and land at the Utah Test and Training Range in 2023. The capsule will then be transported to JSC for processing by a dedicated research facility. Subsamples will be made available for research to the world-wide science community.

## ACHIEVEMENTS IN FY 2011

Final selection of OSIRIS-REx for the third New Frontiers mission occurred as planned in FY 2011, allowing the New Frontiers 3 mission to proceed into Phase B in FY 2012.

## KEY ACHIEVEMENTS PLANNED FOR FY 2013

In March 2013, the project will complete its Preliminary Design Review (PDR) and proceed to design and development phase (phases C and D).

# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER (OSIRIS-REX)

| Formulation | Development | Operations |
|---|---|---|

## ESTIMATED PROJECT SCHEDULE

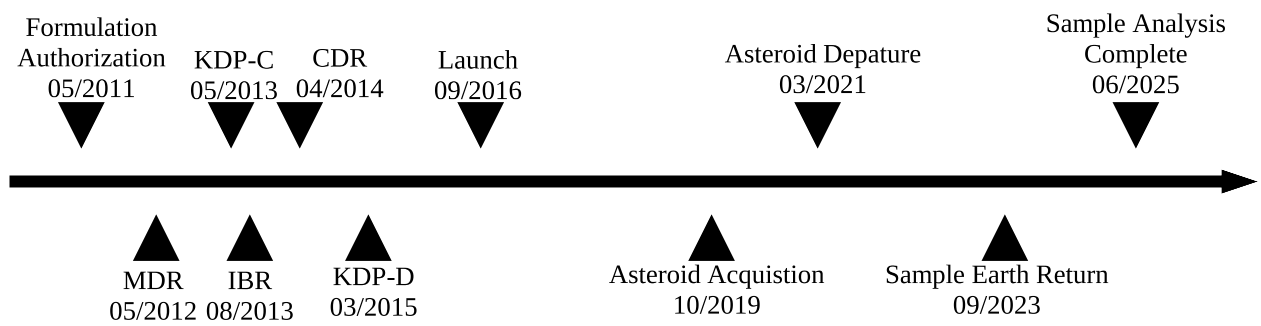
OSIRIS-REx is tentatively scheduled for launch in the 3rd quarter of FY 2016 to an asteroid for a sample return mission. This project is being reported for the first time in this FY 2013 budget submission.

| Formulation Milestones | Formulation Agreement Estimate | FY 2013 PB Request Date |
|---|---|---|
| Formulation Authorization | May-11 | May-11 |
| Mission Definition Review | May-12 | May-12 |
| KDP-C | May-13 | May-13 |
| Integrated Baseline Review | Aug-13 | Aug-13 |
| CDR | Apr-14 | Apr-14 |
| KDP-D | Mar-15 | Mar-15 |
| Launch | Sep-16 | Sep-16 |
| Asteroid Acquisition | Oct-19 | Oct-19 |
| Asteroid Departure | Mar-21 | Mar-21 |
| Sample Earth Return | Sep-23 | Sep-23 |
| Sample Analysis Complete | Jun-25 | Jun-25 |

# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER (OSIRIS-REX)

| | | |
|---|---|---|
| Formulation | Development | Operations |

## Project Schedule




## Formulation Estimated Life Cycle Cost Range and Schedule Range Summary

| KDP-B Date | Estimated Life Cycle Cost Range ($M) | Key Milestone | Key Milestone Estimated Date Range |
|---|---|---|---|
| 5/2011 | 1085-1210 | LRD | 3/2016-9/2016 |

## Project Management & Commitments

The OSIRIS-REx project will be managed by GSFC, which will also provide systems engineering, safety and mission assurance, project scientists, flight dynamics, and the OVIRS instrument. JSC will curate and manage the returned sample, and MSFC will manage the project under its New Frontiers Program Office. The University of Arizona will provide the principle investigator, science team coordination, Planetary Data Systems archiving, education and public outreach, and provide the OCAMS instrument.

# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER (OSIRIS-REX)

| Formulation | Development | Operations |
|---|---|---|

| Project/Element | Provider | Description | FY 2012 PB | FY 2013 PB |
|---|---|---|---|---|
| Spacecraft | Provider: Lockheed Martin<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: None | The OSIRIS-REx payload includes instruments from the University of Arizona, GSFC, Arizona State University in Tempe and CSA | N/A | New |
| Spacecraft Navigation | Provider: KinetX<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: None | Radio science provides RQ36 mass and gravity field maps | N/A | New |
| OSIRIS-REx Camera Suite (OCAMS) | Provider: University of Arizona<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: None | Provides long-range acquisition of RQ36, along with global mapping, sample-site characterization, sample acquisition documentation, and sub-mm imaging | N/A | New |
| OSIRIS-REx Laser Altimeter (OLA) | Provider: CSA<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: CSA | Provides ranging data; global topographic mapping; and local topographic maps of candidate sample sites | N/A | New |
| OSIRIS-REx Visible and IR Spectrometer (OVIRS) | Provider: GSFC<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: None | Provides mineral and organic spectral maps and local spectral information of candidate sample sites | N/A | New |
| OSIRIS-REx Thermal Emission Spectrometer (OTES) | Provider: Arizona State University<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: None | Provides mineral and thermal emission spectral maps and local spectral information of candidate sample sites | N/A | New |
| Launch Vehicle | Provider: Boeing<br>Project Management: KSC<br>NASA Center: GSFC<br>Cost Share: None | Launch vehicle | N/A | New |

# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER (OSIRIS-REX)

| Formulation | Development | Operations |
| --- | --- | --- |

## Project Risks

| Risk Statement | Mitigation |
| --- | --- |
| If: The launch vehicle vibro-acoustic loads exceed heritage design capabilities and/or qualifications,<br>Then: Redesign or requalification of heritage designs at the higher load levels may be necessary with cost and schedule impacts, | Perform early vibro-acoustic analysis with KSC to demonstrate more accurate vibro-acoustic loads. After analysis, new launch vehicle load information will be provided to determine propagated loads and effects on heritage designs. |
| If: The Sample Return Capsule reentry is anomalous,<br>Then: The return sample will be compromised (lost or contaminated). | Designate a lead for the Entry/Descent/Landing at Lockheed Martin; use same experienced flight dynamics/Entry/Descent/Landing team as Stardust; use same designs, fabrication, and test program as Stardust for the Sample Return Capsule. |

## Acquisition Strategy

### MAJOR CONTRACTS/AWARDS

Due to the recent down selection of the project in late FY 2011, there are no major contracts currently in place.

### INDEPENDENT REVIEWS

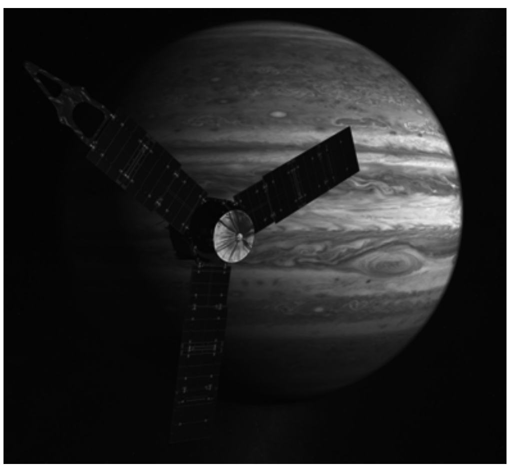
| Review Type | Performer | Last Review | Purpose/Outcome | Next Review |
| --- | --- | --- | --- | --- |
| Performance | SRB | None | Preliminary Design Review | Mar-13 |
| Performance | SRB | None | Non-Advocate Review | Apr-13 |
| Performance | SRB | None | Critical Design Review | Apr-14 |

# OTHER MISSIONS AND DATA ANALYSIS

| Formulation | Development | Operations |
|---|---|---|

## FY 2013 BUDGET

| | Actual | Estimate | | Notional | | | |
|---|---|---|---|---|---|---|---|
| **Budget Authority (in $ millions)** | **FY 2011** | **FY 2012** | **FY 2013** | **FY 2014** | **FY 2015** | **FY 2016** | **FY 2017** |
| **FY 2013 President's Budget Request** | **208.3** | **50.5** | **37.5** | **41.0** | **55.4** | **57.8** | **110.1** |
| New Frontiers Future Missions | 2.6 | 0.0 | **0.0** | 0.0 | 0.0 | 2.5 | 65.3 |
| New Frontiers Management | 5.7 | 6.4 | **6.4** | 6.5 | 6.7 | 6.9 | 7.0 |
| New Frontiers Research | 1.2 | 0.3 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 |
| New Horizons | 9.7 | 12.4 | **13.3** | 16.4 | 26.8 | 18.5 | 4.5 |
| Juno | 189.2 | 31.4 | **17.8** | 18.1 | 21.8 | 29.9 | 33.4 |
| Change From FY 2012 Estimate | -- | -- | **-13.0** | | | | |
| Percent Change From FY 2012 Estimate | -- | -- | **-25.8%** | | | | |



**This is the first time a spacecraft has used solar power so far out in space (Jupiter is five times farther from the Sun than Earth). To operate on the Sun's light that far out requires solar panels about 9 feet wide by 29 feet long, about the size of the cargo section of a typical tractor-trailer. The panels will only generate enough power for five standard light bulbs, about 450 watts of electricity. If the arrays were optimized to operate at Earth, they would produce 12 to 14 kilowatts of power.**

The New Frontiers program represents a critical step in the advancement of solar system exploration. The missions in the program will tackle specific solar system exploration goals identified as top priorities by consensus of the planetary community as reported in the planetary science decadal surveys conducted by the National Academies. NASA's goals are to:

Examine the "big picture" of solar system exploration today—what it is, how it fits into other scientific endeavors, and why it is a compelling goal; (i.e. understanding solar system beginnings, and searching for the requirements for life);
Perform a broad survey of the current state of knowledge about our solar system (i.e. revealing planetary processes through time);
Obtain an inventory of the top-level scientific questions that should provide the focus for solar system exploration in the next decade; and
Generate a prioritized list of the most promising avenues for flight investigations and supporting ground-based activities.

# OTHER MISSIONS AND DATA ANALYSIS

| Formulation | Development | Operations |
|---|---|---|

## Non-Operating Missions

### NEW FRONTIERS FUTURE MISSIONS

The New Frontiers Future Missions project provides funds for future New Frontiers space missions to be selected via a competitive Announcement of Opportunity process. The third New Frontiers mission, OSIRIS-REx, was announced in May 2011. The fourth announcement of opportunity (NF-4) release for competition is currently planned for 2015. Based on their science value and projected costs, the 2013 Planetary Science Decadal Survey committee identified five candidate New Frontiers missions, which can be found at http://www.nap.edu/catalog.php?record_id=13117#toc.

### NEW FRONTIERS MANAGEMENT

New Frontiers Management provides for the management oversight of flight missions selected for the program. It also supports the mission selection process, through the development of Announcements of Opportunity and the establishment of independent panel reviews to evaluate mission proposals.

## Operating Missions

### NEW HORIZONS

New Horizons is the first scientific investigation to obtain a close look at Pluto and its moons Charon, Nix, Hydra, and S/2011 P1. Scientists hope to find answers to basic questions about the surface properties, geology, interior makeup and atmospheres on these bodies, the last in our solar system to be visited by a spacecraft.

New Horizons launched on January 19, 2006. It performed a Jupiter gravity assist and scientific studies in early 2007 and will reach Pluto in July 2015. As part of an extended mission, the spacecraft would then head deeper into the Kuiper Belt to study one or more of the icy mini-worlds in the region one billion miles beyond Neptune’s orbit.

To get to Pluto, which is three billion miles from Earth, in just 9.5 years, the spacecraft will fly by the dwarf planet Pluto and its four moons in 2015 at a velocity of about 27,000 miles per hour. The instruments on New Horizons will start taking data on Pluto and Charon months before it arrives. About three months from the closest approach, when Pluto and its moons are about 65 million miles away, the instruments will take images and spectra measurements and begin to make the first maps ever made of these bodies.

The spacecraft will get as close as about 6,000 miles from Pluto and about 17,000 miles from Charon. During the half-hour when the spacecraft is closest to Pluto, it will take close-up pictures in both visible and near-infrared wavelengths. The best images should depict surface features as small as 200 feet across.

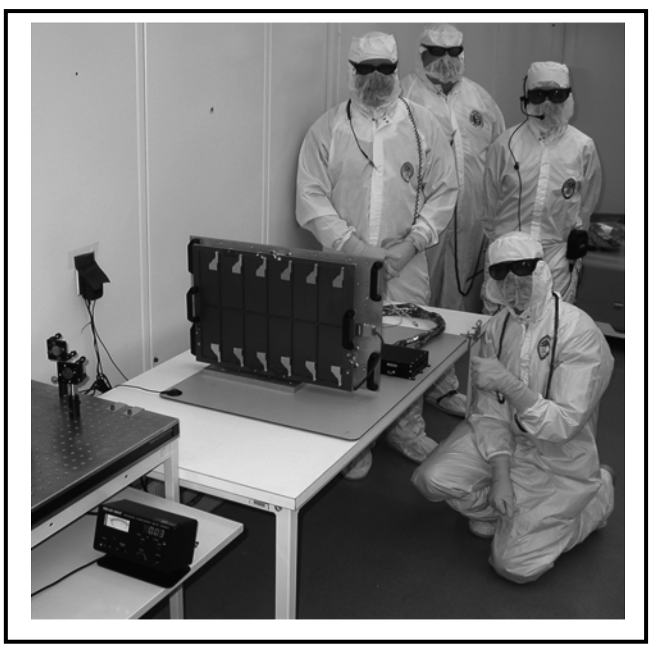
# OTHER MISSIONS AND DATA ANALYSIS

| Formulation | Development | Operations |
|---|---|---|

## JUNO

Juno is a mission of discovery and exploration that will conduct an in-depth study of Jupiter, the most massive planet in our solar system. Peering through the clouds deep into Jupiter's atmosphere, the mission will reveal fundamental processes of the formation and early evolution of our solar system. Juno's goal is to understand the origin and evolution of the gas giant planet, which will pave the way to a better understanding of our solar system and other planetary systems being discovered around other stars. Juno was successfully launched on August 5, 2011 as scheduled and within the budget allocated for development of this mission.

Using a spinning, solar-powered spacecraft, Juno will make maps of the gravity, magnetic fields, and atmospheric composition of Jupiter from a unique polar orbit. Juno will carry precise high-sensitivity radiometers, magnetometers, and gravity science systems. During its approximately one-year mission, Juno will complete 33 eleven-day-long orbits and will sample Jupiter's full range of latitudes and longitudes. From its polar perspective, not mapped before, Juno combines in situ and remote sensing observations to explore the polar magnetosphere and determine what drives Jupiter's remarkable auroras. Juno has a camera on board to produce images focused on education and public outreach.



## Recent Achievements

### NEW HORIZONS STUDENT DUST COUNTER INSTRUMENT BREAKS DISTANCE RECORD

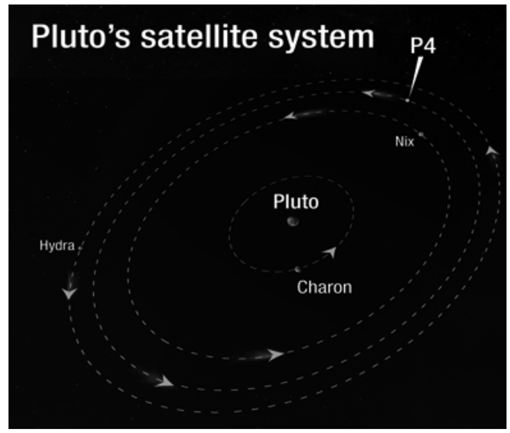
The Student Dust Counter surpassed the previous record when it flew beyond 18 astronomical units, one unit is the distance between the Sun and the Earth, or 1.67 billion miles, approaching the orbit of Uranus. The only other dedicated instruments to measure space dust beyond Jupiter's orbit were aboard Pioneers 10 and 11 in the 1970s. Additionally, the instrument is the first science instrument on a planetary mission to be designed, tested and operated by students. The instrument was built by students from the University of Colorado. The New Horizons project is managed by the Southwest Research Institute (SwRI).

# OTHER MISSIONS AND DATA ANALYSIS

| Formulation | Development | Operations |
|---|---|---|

## FOURTH MOON AROUND PLUTO CONFIRMED BY NEW HORIZONS

New Horizons mission team scientists confirmed the discovery of a fourth moon around Pluto, first discovered via the Hubble Space Telescope in June 2011. The New Horizons project is managed by SwRI.



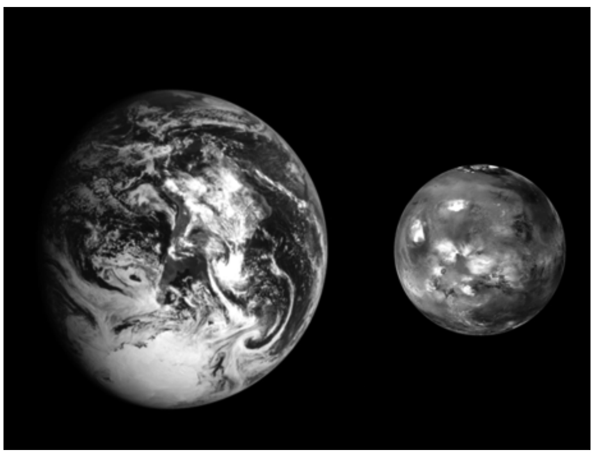

## NASA'S JUNO SPACECRAFT LAUNCHES TO JUPITER

NASA's first solar-powered spacecraft to Jupiter lifted off from Cape Canaveral Air Force Station aboard an Atlas V rocket, to begin a five-year journey to Jupiter. Juno's detailed study of the largest planet in our solar system will help reveal Jupiter's origin and evolution. As the archetype of giant gas planets, Jupiter can help scientists understand the origin of our solar system and learn more about planetary systems around other stars. The Juno project is managed by JPL.

# MARS EXPLORATION

## FY 2013 BUDGET

| Budget Authority (in $ millions) | Actual FY 2011 | Estimate FY 2012 | FY 2013 | Notional FY 2014 | FY 2015 | FY 2016 | FY 2017 |
|---|---|---|---|---|---|---|---|
| **FY 2013 President's Budget Request** | **547.4** | **587.0** | **360.8** | **227.7** | **188.7** | **266.9** | **503.1** |
| MAVEN | 160.6 | 245.7 | **146.4** | 37.6 | 17.3 | 5.3 | 0.0 |
| Other Missions and Data Analysis | 386.8 | 341.4 | **214.4** | 190.1 | 171.4 | 261.6 | 503.1 |
| Change From FY 2012 Estimate | -- | -- | **-226.2** | | | | |
| Percent Change From FY 2012 Estimate | -- | -- | **-38.5%** | | | | |



**Every time we feel close to understanding Mars, new discoveries send us straight back to the drawing board to revise existing theories. NASA's discovered that today's Martian wasteland hints at a formerly volatile world where volcanoes once raged, meteors plowed deep craters, and flash floods rushed over the land. Mars continues to throw out new enticements with each landing or orbital pass made by spacecraft.**

The Mars Exploration program is a science-driven program that seeks to understand whether Mars was, is, or can be, a habitable world. To find out, we need to understand how geologic, climatic, and other processes have worked to shape Mars and its environment over time, as well as how they interact today. As the most Earth-like planet in our solar system, Mars has a land mass approximately equivalent to the Earth's as well as many of the same familiar features such as riverbeds, past river deltas, and volcanoes. Mars has the best planetary record of the first billion years of our solar system and holds scientific clues to the development of the solar system, planets, and maybe life itself. Mars also has many of the same "systems" that characterize our home world, such as an atmosphere, a hydrosphere, a cryosphere and a lithosphere. In other words, Mars has systems of air, water, ice, and geology that all interact to produce the Martian environment. What we don't know yet is whether Mars ever developed or maintained a biosphere, an environment in which life could thrive. The key to understanding the past, present or future potential for life on Mars can be found in the four broad, overarching goals for Mars Exploration: determine whether life ever arose on Mars, characterize the climate of Mars, characterize the geology of Mars, and prepare for human exploration. The Mars Exploration program has been developed to conduct a rigorous, incremental, discovery-driven exploration of Mars to determine the planet's physical, dynamic, and geological characteristics. This coupled mission and research strategy has yielded significant success in answering many key questions as the program "Followed the Water," and in only a single decade is now able to move to more challenging inquiries of "Seeking the Signs of Life."

Projects under the Mars Exploration program include the current operating missions 2001 Mars Odyssey, 2003 Mars Exploration Rover (MER), Mars Express with the European Space Agency, 2005 Mars

Reconnaissance Orbiter (MRO), and the 2011 Mars Science Laboratory (MSL) that successfully launched in November 2011. The 2013 MAVEN mission is in development.

The Mars Exploration program also includes Mars Program Management, Mars Technology, Mars Operating and Extended Missions, and Mars Research and Analysis. JPL has program management responsibility for the Mars Exploration program, providing overall mission implementation management.

## EXPLANATION OF MAJOR CHANGES FOR FY 2013

After 2013 MAVEN, the Mars Exploration program is working towards defining future missions that will build upon scientific discoveries from past missions and incorporate the lessons learned from previous mission successes and failures. NASA is terminating further activity on the formulation activity for the NASA/ ESA ExoMars Trace Gas Orbiter 2016 (EMTGO) mission and planning for the previous NASA/ESA Mars 2018 mission concept. NASA remains committed to an ongoing Mars Exploration program of robotic exploration missions in support of an integrated strategy of scientific and human exploration, and intends to work with the science community and our international partners in the formulation of a restructured mission.

## ACHIEVEMENTS IN FY 2011

On June 22, 2011, NASA announced Gale Crater as the landing site for MSL's car-sized rover, Curiosity. This was one of the important last milestones for preparing the mission for launch. The MSL mission successfully launched MSL and its Curiosity rover, NASA's largest rover yet, toward Mars in November 2011, and will spend most of FY 2012 cruising to its destination. Curiosity is scheduled to land on the surface of Mars in August 2012 using a groundbreaking "Sky Crane" landing system that will assist in the very difficult task of entry, descent, and landing, which is also intended as a workhorse for landing large-mass systems on the surface of Mars for the foreseeable future.

2013 MAVEN entered the development phase in the opening days of FY 2011 and successfully completed its CDR on July 15, 2011. This review granted permission to the mission team to begin manufacturing flight and ground hardware. 2013 MAVEN is working toward System Integration Review to enable approval to enter Phase D, including Operational and Flight Readiness Reviews, by the end of FY 2012.

## KEY ACHIEVEMENTS PLANNED FOR FY 2013

MSL will have landed on Mars at the beginning of FY 2013 and will have just started surface science operations. These science operations will extend throughout FY 2013, and constitute the first half of the primary mission for MSL. 2013 MAVEN will ship to KSC in mid-2013 for launch in early FY 2014. Future mission concepts will mature and one or more will enter the pre-formulation phase.

# MARS EXPLORATION

## BUDGET EXPLANATION

The FY 2013 request is $360.8 million. This represents a $226.2 million decrease from the FY 2012 estimate ($587.0 million).

With the successful launch of MSL in early FY 2012, the mission entered Operations phase and requires much less funding indicative of significant reductions in the workforce. 2013 MAVEN funding requirements will also decrease in FY 2013 as the project sheds workforce and enters assembly, test, and launch operations in preparation for an early FY 2014 launch. In FY 2012, NASA is ending work on the EMTGO 2016 and the Mars Organic Molecule Analyzer (MOMA). A future Mars mission planned within the Mars Next Decade project is being defined.

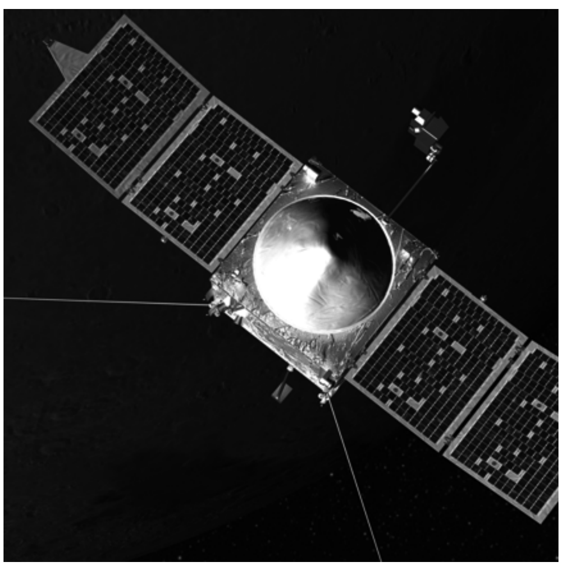
Mars Exploration program re-planning efforts have begun with a cross-discipline team from the Science Mission Directorate, Human Exploration and Operations Mission Directorate, and the Office of the Chief Technologist. This team will engage the broader community in early February 2012 to begin to create a Mars program architecture that includes missions to synergize science and human exploration goals and objectives, plus opportunities for demonstration of key related technologies. The team will look to take advantage of the favorable relative location of Mars and Earth in 2018 and 2020, with pathway options for missions later in the 2020s based on science discovery and human destination requirements. NASA will inform Congress as the new program architecture is defined, and will identify the first mission in the FY 2014 budget request.

# 2013 MARS ATMOSPHERE & VOLATILE EVOLUTION (MAVEN)

| Formulation | Development | Operations |
|---|---|---|

## FY 2013 BUDGET

| Budget Authority (in $ millions) | Prior | Actual FY 2011 | Estimate FY 2012 | FY 2013 | FY 2014 | FY 2015 | FY 2016 | FY 2017 | BTC | LCC Total |
|---|---|---|---|---|---|---|---|---|---|---|
| **FY 2013 President's Budget Request** | **58.4** | **160.6** | **245.7** | **146.4** | **37.6** | **17.3** | **5.3** | **0.0** | **0.0** | **671.2** |
| **2012 MPAR Project Cost Estimate** | **58.4** | **160.6** | **245.7** | **146.4** | **37.6** | **17.3** | **5.3** | **0.0** | **0.0** | **671.2** |
| Formulation | **58.4** | 5.5 | 0.0 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 63.9 |
| Development/ Implementation | **0.0** | 155.0 | 245.7 | **146.4** | 20.1 | 0.0 | 0.0 | 0.0 | 0.0 | 567.2 |
| Operations/close-out | 0.0 | 0.0 | 0.0 | **0.0** | 17.5 | 17.3 | 5.3 | 0.0 | 0.0 | 40.1 |
| Change From FY 2012 Estimate | | -- | -- | **-99.3** | | | | | | |
| Percent Change From FY 2012 Estimate | | -- | -- | **-40.4%** | | | | | | |



**After arriving at Mars in the fall of 2014, MAVEN will use its propulsion system to enter an elliptical orbit ranging 90 to 3,870 miles above the planet. The spacecraft's eight science instruments will take measurements for a full Earth year, obtaining critical measurements that the National Academy of Science listed high priority in their 2003 decadal survey on planetary exploration.**

## EXPLANATION OF MAJOR CHANGES FOR FY 2013

2013 MAVEN completed its Critical Design Review on July 15, 2011, progressing towards a November 2013 launch date. The above funding estimate reflects the October 2010 decision to allow the project to enter development phase. This reflects the addition of Electra, a UHF software defined radio designed to communicate with other spacecraft as they approach, land, and operate on Mars, and the awarded launch vehicle costs. The project's development and life cycle cost estimates and schedule in this document are consistent with the KDP-C memo and its baseline report.

## PROJECT PURPOSE

2013 MAVEN was selected under the Mars Scout program, which supports smaller, low-cost competed missions led by a principal investigator. 2013 MAVEN will provide a comprehensive picture of the Mars upper atmosphere, ionosphere, solar energetic drivers, and atmospheric losses.

# 2013 MARS ATMOSPHERE & VOLATILE EVOLUTION (MAVEN)

| Formulation | Development | Operations |
|---|---|---|

2013 MAVEN will deliver answers to long-standing questions regarding the loss of the Mars atmosphere, climate history, liquid water, and habitability. 2013 MAVEN will provide the first direct measurements ever taken to address key scientific questions about Mars' evolution. Specific 2013 MAVEN science objectives are to determine structure and composition of the atmosphere and ionosphere; determine the physical and chemical processes that control loss processes; determine escape rates of neutrals; determine escape rates of ions; determine the external inputs that control upper atmosphere and ionosphere structure and that drive escape; and determine the relative escape rates of the stable isotopes and the resulting isotopic fractionation. As with all Mars Exploration program orbiters, 2013 MAVEN will also carry an Electra radio for communications with surface assets.

## PROJECT PARAMETERS

2013 MAVEN will deliver its science using three instrument packages: A stand-alone neutral gas and ion mass spectrometer, capable of measuring thermal neutrals and ions; a stand-alone imaging ultraviolet spectrometer; and the Particles and Fields package, consisting of six instruments measuring ionospheric properties, energetic ions, solar wind and solar energetic particles, magnetic fields, and solar extreme ultraviolet irradiance.

## ACHIEVEMENTS IN FY 2011

2013 MAVEN completed its Critical Design Review on July 15, 2011.

## KEY ACHIEVEMENTS PLANNED FOR FY 2013

2013 MAVEN will ship to Cape Canaveral in July 2013 and commence launch operations processing shortly thereafter for launch in November 2013.

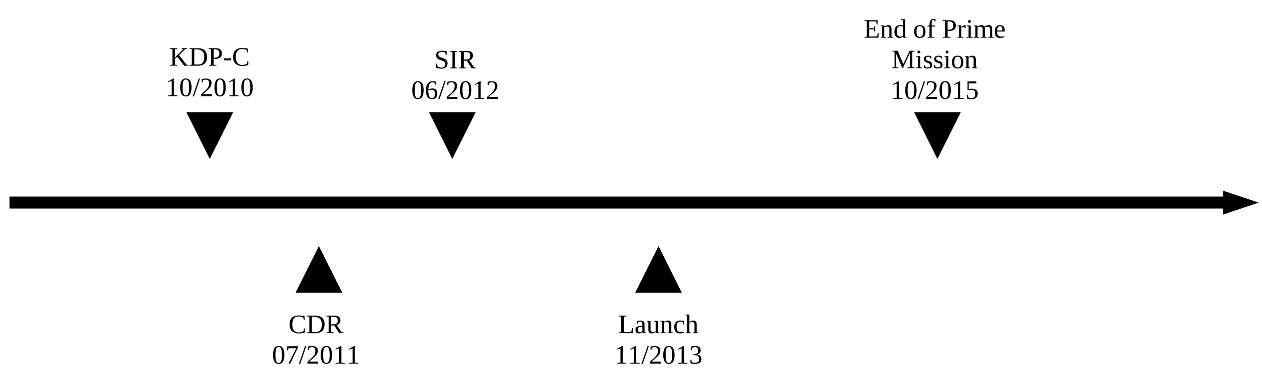
# 2013 MARS ATMOSPHERE & VOLATILE EVOLUTION (MAVEN)

| Formulation | Development | Operations |
|---|---|---|

## SCHEDULE COMMITMENTS/KEY MILESTONES

| Development Milestones | Confirmation Baseline Date | FY 2013 PB Request Date |
|---|---|---|
| KDP-C | Oct-10 | Oct-10 |
| CDR | Jul-11 | Jul-11 |
| SIR | Jun-12 | Jun-12 |
| Launch | Nov-13 | Nov-13 |
| End of Prime Mission | Oct-15 | Oct-15 |

## Project Schedule



# 2013 MARS ATMOSPHERE & VOLATILE EVOLUTION (MAVEN)

| Formulation | Development | Operations |
|---|---|---|

## Development Cost and Schedule

| Base Year | Base Year Development Cost Estimate ($M) | JCL (%) | Current Year | Current Year Development Cost Estimate ($M) | Cost Change (%) | Key Milestone | Base Year Milestone Date | Current Year Milestone Date | Milestone Change (months) |
|---|---|---|---|---|---|---|---|---|---|
| 2011 | 567.2 | 70 | 2012 | 567.2 | 0 | LRD | Nov-13 | Nov-13 | 0 |

Note: *The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. The estimate above reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as joint confidence level; all other confidence levels reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

## Development Cost Details (in $M)

| Element | Base Year Development Cost Estimate | Current Year Development Cost Estimate | Change from Base Year Estimate |
|---|---|---|---|
| **TOTAL:** | **567.2** | **567.2** | **0.0** |
| Aircraft/Spacecraft | 146 | 164.2 | 18.2 |
| Payloads | 51.1 | 53.2 | 2.1 |
| Systems I&T | 23 | 21.6 | -1.4 |
| Launch Vehicle | 187 | 186.3 | -0.7 |
| Ground Systems | 5.2 | 5.9 | 0.7 |
| Science/Technology | 2.2 | 2.2 | 0.0 |
| Other Direct Project Costs | 152.7 | 133.8 | -18.9 |

# 2013 MARS ATMOSPHERE & VOLATILE EVOLUTION (MAVEN)

| Formulation | Development | Operations |
|---|---|---|

## Project Management & Commitments

The 2013 MAVEN project is part of the Mars Exploration program managed for NASA by the Mars Program Office at JPL. The principle investigator for 2013 MAVEN is from the University of Colorado and has delegated the day-to-day management of the 2013 MAVEN project to GSFC.

| Project/Element | Provider | Description | FY 2012 PB | FY 2013 PB |
|---|---|---|---|---|
| Spacecraft | Provider: Lockheed Martin<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | MRO heritage spacecraft bus and avionic suite, with cross strapping and monopropellant propulsion | Same | Same |
| Launch Vehicle | Provider: ULA<br>Project Management: KSC<br>NASA Center: KSC<br>Cost Share: N/A | Atlas V launch vehicle and related launch services | Same (reported as intermediate class launch service, Atlas V now selected) | Same |
| Neutral gas and ion mass spectrometer | Provider: GSFC<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | Design, build, and deliver the instrument | Same | Same |
| Magnetometer | Provider: GSFC<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | Design, build, and deliver (part of the MAVEN Particle and Fields Instrument package) | Same | Same |
| Imaging Ultraviolet Spectrometer | Provider: University of Colorado, LASP<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | Design, build, and deliver remote sensing instrument package. | Same | Same |
| Electra | Provider: JPL<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | Design, build, and deliver UHF Data Relay payload | Same | Same |

# 2013 MARS ATMOSPHERE & VOLATILE EVOLUTION (MAVEN)

| Formulation | Development | Operations |
|---|---|---|

| Project/Element | Provider | Description | FY 2012 PB | FY 2013 PB |
|---|---|---|---|---|
| Supra Thermal Ion Composition | Provider: SSL<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | Design, build, and deliver (part of Particle and Fields Instrument package) | Same | Same |
| Solar Energetic Particles | Provider: SSL<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | Design, build, and deliver UHF Data Relay payload | Same | Same |
| Solar Wind Electron Analyzer | Provider: SSL<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | Design, build, and deliver UHF Data Relay payload | Same | Same |
| Solar Wind Ion Analyzer | Provider: GSFC<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | Design, build, and deliver the NGIMS instrument | Same | Same |
| Lanamuir Probe and Waves and EUV | Provider: SSL<br>Project Management: GSFC<br>NASA Center: GSFC<br>Cost Share: N/A | Design, build, and deliver UHF Data Relay payload | Same | Same |

## Project Risks

| Risk Statement | Mitigation |
|---|---|
| If: single point failures on the input of the HEPS card occur,<br>Then: permanent loss of spacecraft electrical power will result. | The project and GSFC Mission Assurance Office are identifying and understanding HEPS-specific manufacturing techniques; identifying all single point failures to inspect during assembly to mitigate against shorts; developing a plan for insight/oversight of the 2013 MAVEN-specific HEPS card build; reviewing board requirements with an eye towards design robustness and remaining design requirements. |

# 2013 MARS ATMOSPHERE & VOLATILE EVOLUTION (MAVEN)

| Formulation | Development | Operations |
| --- | --- | --- |

## Acquisition Strategy

### MAJOR CONTRACTS/AWARDS

| Element | Vendor/Provider | Location |
| --- | --- | --- |
| Spacecraft, flight system, integration & test, mission operations | Lockheed Martin Space Systems Company | Denver, CO |
| Launch Vehicle & services | United Launch Alliance | Florida |

### INDEPENDENT REVIEWS

| Review Type | Performer | Last Review | Purpose/Outcome | Next Review |
| --- | --- | --- | --- | --- |
| Performance | SRB | Jul-11 | The 2013 MAVEN Project passed the CDR conducted by the independent Standing Review Board in July 2011. | N/A |
| Performance | SRB | N/A | Assess readiness to proceed to observatory integration and test | Jun-12 |

# OTHER MISSIONS AND DATA ANALYSIS

| Formulation | Development | Operations |
|---|---|---|

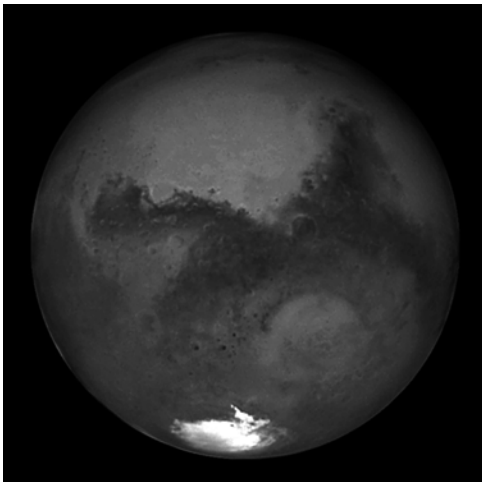
## FY 2013 BUDGET

| | Actual | Estimate | | Notional | | | |
|---|---|---|---|---|---|---|---|
| **Budget Authority (in $ millions)** | **FY 2011** | **FY 2012** | **FY 2013** | **FY 2014** | **FY 2015** | **FY 2016** | **FY 2017** |
| **FY 2013 President's Budget Request** | **386.8** | **341.4** | **214.4** | **190.1** | **171.4** | **261.6** | **503.1** |
| Mars Research and Analysis | 17.4 | 19.0 | **15.2** | 15.2 | 15.3 | 15.3 | 15.3 |
| Mars Technology | 2.5 | 5.0 | **3.0** | 4.0 | 7.0 | 23.0 | 75.0 |
| Mars Mission Operations | 1.6 | 1.8 | **1.8** | 1.8 | 1.9 | 1.9 | 1.9 |
| Mars Extended Operations | 0.0 | 0.0 | **53.7** | 40.1 | 56.3 | 51.2 | 51.4 |
| Mars Next Decade | 8.0 | 4.3 | **62.0** | 72.8 | 72.8 | 151.7 | 346.1 |
| Mars Program Management | 21.0 | 27.5 | **13.5** | 17.6 | 18.1 | 18.5 | 13.4 |
| 2001 Mars Odyssey | 10.1 | 12.8 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 |
| 2003 Mars Exploration Rover | 13.6 | 15.0 | **0.1** | 0.0 | 0.0 | 0.0 | 0.0 |
| Mars Express | 0.9 | 2.1 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 |
| 2005 Mars Reconnaissance Orbiter | 30.1 | 40.4 | **0.1** | 0.0 | 0.0 | 0.0 | 0.0 |
| 2011 Mars Science Laboratory | 242.9 | 174.0 | **65.0** | 38.5 | 0.0 | 0.0 | 0.0 |
| Mars Organic Molecule Analyzer | 6.0 | 11.9 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 |
| 2016 ExoMars Trace Gas Orbiter | 32.6 | 27.6 | **0.0** | 0.0 | 0.0 | 0.0 | 0.0 |
| Change From FY 2012 Estimate | -- | -- | **-127.0** | | | | |
| Percent Change From FY 2012 Estimate | -- | -- | **-37.2%** | | | | |

NASA's Mars Exploration program has been developed to conduct a rigorous, incremental, discovery-driven exploration of Mars to determine the planet's physical, dynamic, and geological characteristics. The Other Missions and Data Analysis budget line currently includes five operating missions: 2001 Mars Odyssey, 2003 Mars Exploration Rover, Mars Express, 2005 Mars Reconnaissance Orbiter (MRO), and the 2011 Mars Science Laboratory that successfully launched in November 2011. Six non-mission components are also included: Mars Research and Analysis, Mars Technology, Mars Mission Operations, Mars Extended Operations, Mars Next Decade, and Mars Program Management.

# OTHER MISSIONS AND DATA ANALYSIS

| Formulation | Development | Operations |
|---|---|---|



**Home to the largest volcano in the solar system, the deepest canyon, and crazy weather and temperature patterns, Mars will become host to Mars Science Laboratory (MSL), whose scheduled arrival is Aug. 5, 2012, PDT (Aug. 6, EDT and Universal Time). The MSL mission will use its car-size rover, Curiosity, to investigate whether the selected region inside Gale Crater has offered environmental conditions favorable for supporting microbial life and preserving clues about whether life existed on Mars.**

## Non-Operating Missions

### MARS RESEARCH AND ANALYSIS

Mars Research and Analysis provides funding for research and analysis of Mars mission data in order to understand how geologic, climatic, and other processes have worked to shape Mars and its environment over time, as well as how they interact today. Specific investments include:

- Mars Fundamental Research program, which funds fundamental research in laboratory studies, field studies, or theoretical studies that inform us about Mars;
- Mars Data Analysis, which analyzes archived data collected on Mars missions;
- Critical Data Products, which provides data for the safe arrival, aero-maneuver, entry, descent, and landing at Mars; and
- MRO and MSL Participating Scientists programs that fund participating scientists for the MRO mission.

Data access through Mars R&A allows a much broader, and perhaps more objective analysis of the data and samples, and also allows research to continue for many years after the mission has been completed. Areas for additional data analyses are proposed by scientists throughout the U.S. planetary community and are competitively selected with major input from science community peer review.

### MARS TECHNOLOGY

Mars Technology focuses on technology investments that lay the groundwork for successful future Mars missions, such as instrument capabilities; sample handling and processing technologies; entry, descent and landing capabilities; and surface-to-orbit communications improvements (e.g. Electra).

### MARS MISSION OPERATIONS

Mars Mission Operations provides management and leadership for the development and execution of Mars multi-mission operations. Mars Mission Operations supports and provides common operational systems and capabilities at a lower cost and risk than having Mars projects produce systems individually.

# OTHER MISSIONS AND DATA ANALYSIS

| Formulation | Development | Operations |
|---|---|---|

## MARS EXTENDED OPERATIONS

Mars Extended Operations provides funding to missions that have concluded their primary mission phase, thereby allowing for science operations and discoveries. Funding for mission extensions is allocated based on the findings of an annual, competitive senior review board process. Their review of each mission enables them to make recommendations for the allocation of the extended operations budget based on scientific merit.

## MARS NEXT DECADE

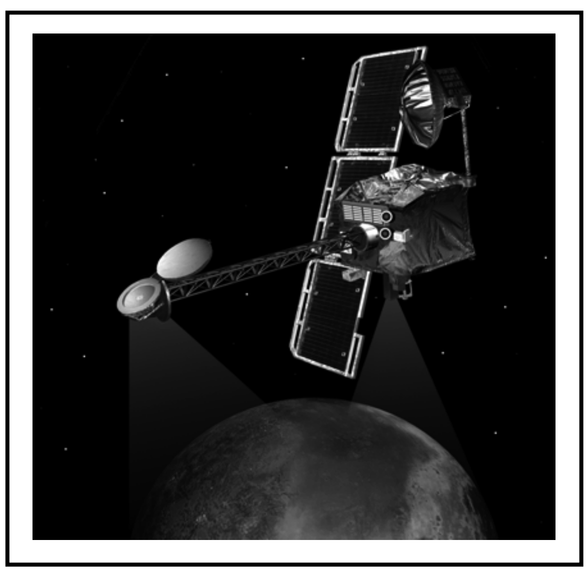
Mars Next Decade provides funds for the planning of future missions to Mars that build on scientific discoveries from past missions and incorporate the lessons learned from previous mission successes and failures. The Mars Exploration program is working with the HEOMD to define future robotic missions that support science and exploration requirements in an integrated strategy.

## MARS PROGRAM MANAGEMENT

Mars Program Management provides for the implementation and management of the Mars Exploration program's selected flight missions. This line also supports independent panel reviews, Mars education and public outreach, planetary protection, advanced studies and program architecture, program science, and telecommunications integration.

# Operating Missions

## 2001 MARS ODYSSEY



2001 Mars Odyssey, currently in its third extended mission operation phase, is still in orbit around Mars and has collected more than 130,000 images and continues to send information to Earth about Martian geology, climate, and mineralogy. Measurements by Odyssey have enabled scientists to create maps of minerals and chemical elements and identify regions with buried water ice. Images that measure the surface temperature have provided spectacular views of Martian topography. Odyssey helped support the landing site selection for the Phoenix Scout Mission and continues to provide future mission landing site data. Early in the mission, Odyssey determined that radiation in low-Mars orbit, an essential piece of information for eventual human exploration because of its potential health effects, is twice that in low-

# OTHER MISSIONS AND DATA ANALYSIS

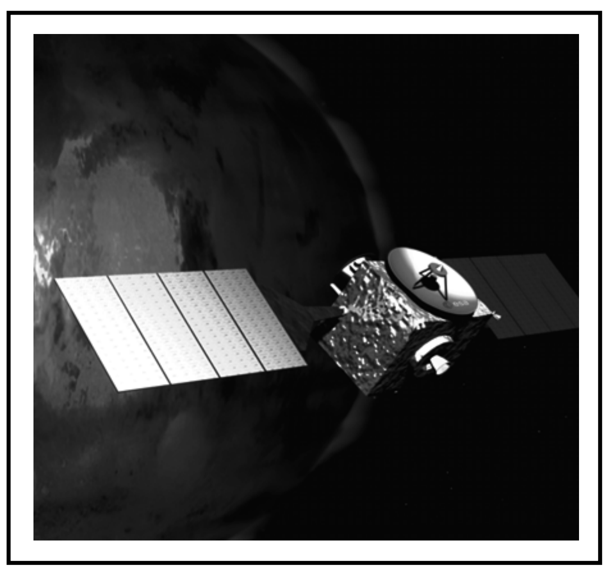


Earth orbit. Odyssey has provided vital support to ongoing exploration of Mars by relaying nearly 100 percent of the data from Spirit/Opportunity to Earth via the spacecraft's UHF system.

## 2003 MARS EXPLORATION ROVER

2003 Mars Exploration Rover, the rover named Opportunity, currently in its extended operation phase, continues to explore geological settings on the surface of Mars using a suite of remote sensing and in-situ instruments. Its objective is to expand our understanding of the history and the geological processes that shaped Mars, particularly those involving water. Opportunity has trekked for miles across the Martian surface conducting field geology and making atmospheric observations, finding evidence of ancient Martian environments where intermittently wet and habitable conditions existed, and sending back to Earth more than 100,000 spectacular, high-resolution, full-color images from Martian terrain to detailed microscopic images of rocks and soils. Special rock abrasion tools, never before sent to another planet, have enabled scientists to peer beneath the dusty and weathered surfaces of rocks to examine their interiors. Opportunity is now preparing to weather a predictably harsh Martian winter, with dirty solar arrays, high atmospheric dust, and low light levels.

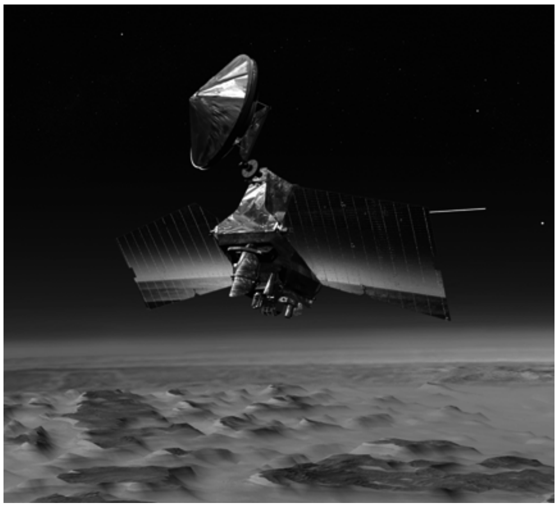
## MARS EXPRESS



Mars Express, currently in its second extended mission operation phase, is a European Space Agency and Italian Space Agency mission whose objective is to search for sub-surface water from orbit. NASA contributed components for the MARSIS and ASPERA instrument aboard Mars Express and participates in the scientific analysis of mission data, including the recent investigations into the mysterious deposits of the Medusae Fossae Formation. Seven scientific instruments on the orbiting spacecraft have conducted rigorous investigations to help answer fundamental questions about the geology, atmosphere, surface environment, history of water, and potential for life on Mars. Examples of discoveries, still debated by scientists, by Mars Express are evidence of recent glacial activity, explosive volcanism, and methane gas.

# OTHER MISSIONS AND DATA ANALYSIS

| Formulation | Development | Operations |
|---|---|---|



## 2005 MARS RECONNAISSANCE ORBITER

2005 Mars Reconnaissance Orbiter (MRO), currently in extended operations phase, carries the most powerful camera ever flown on a planetary exploration mission for homing in on details of Martian terrain with extraordinary clarity. While previous cameras on other Mars orbiters were able to identify objects no smaller than a dinner table, this camera is able to spot something as small as a dinner plate. This capability provides not only an astoundingly detailed view of the geology and structure of Mars, but helps identify obstacles that could jeopardize the safety of future landers and rovers. The 2007 Phoenix landing site in the Martian arctic was changed after MRO identified an excessive number of large boulders in the landing ellipse, and MRO was the main data source for evaluating the safety of the final 4 MSL landing sites. MRO also carries a sounder to find subsurface water, an important consideration in selecting scientifically worthy landing sites for future exploration. Other science instruments on this multitasking, multipurpose spacecraft identify surface minerals and study how dust and water are transported in the Martian atmosphere. A second camera acquires medium-resolution images that provide a broader geological and meteorological context for more detailed observations from higher-resolution instruments. MRO also serves as the first installment of an "interplanetary Internet," a crucial service for future spacecraft as the first link in a communications bridge back to Earth, for surface missions.

## 2011 MARS SCIENCE LABORATORY (MSL)

2011 Mars Science Laboratory, currently on cruise to Mars, takes a major step forward in Mars exploration, both technically and scientifically, using a new entry, descent, and landing system, a long-duration rover, and ten payload instruments for definitive mineralogical and organics measurements. The primary scientific objective is to explore and quantitatively assess a local region on Mars as a potential habitat for life, and is the transitional mission from the "Follow the Water" theme to the "Seeking the Signs of Life" theme. MSL will lay the groundwork for future scientific missions and will provide key information for human exploration. Twice as long and three times as heavy as the MER rover Opportunity, the MSL Curiosity rover will collect Martian soil and rock samples and analyze them for organic compounds and environmental conditions that could have supported microbial life now or in the past. The mission is a truly international partnership, with a neutron-based hydrogen detector for locating water provided by the Russian Federal Space Agency, a meteorological package provided by the Spanish Ministry of Education and Science, and a spectrometer provided by CSA. MSL is the first planetary mission to use precision landing techniques, steering itself toward the Martian surface similar to the way the space shuttle controls its entry through the Earth's upper atmosphere. In this way, the spacecraft is able to fly to a desired location above the surface of Mars before deploying its parachute for the final

# OTHER MISSIONS AND DATA ANALYSIS

| Formulation | Development | Operations |
|---|---|---|

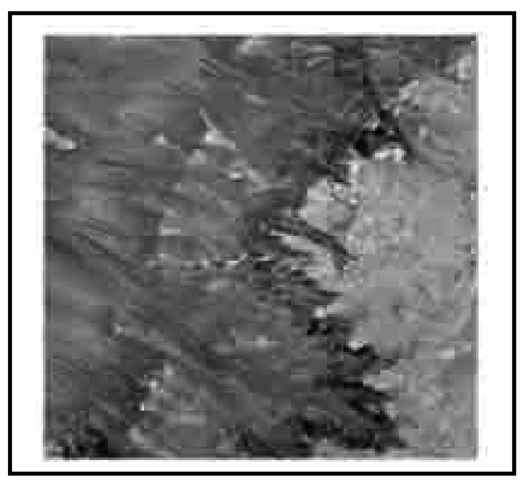
landing. In the final minutes before touchdown, the spacecraft will activate its parachute and retro rockets before lowering the rover package to the surface on a tether (similar to the way a skycrane helicopter moves a large object). This landing method will enable the rover to land in an area about 20 kilometers in diameter, about the size of a small crater or wide canyon, and three to five times smaller than previous landing zones on Mars.

## Recent Achievements

### 2011 MARS SCIENCE LABORATORY

2011 Mars Science Laboratory successfully launched on November 26, 2011. The cruise to Mars will take nine months. Upon landing in August 2012, the MSL rover, named Curiosity through a student competition, will complete a series of automated computer sequences to make sure all systems are operating as expected and to check the immediate environment. After all of these tasks are complete, the rover will make its first drive from the landing zone into the scientifically rich landscape of Gale Crater. The rover will test the many science instruments on board as exploration begins. The end of the primary mission is scheduled for September 2014.

### 2005 MARS RECONNAISSANCE ORBITER



Using the 2005 MRO data, there is a growing collection of evidence indicating that the present surface of Mars is still geologically active. One of the most exciting discoveries is dark markings or streaks, 0.5-5 meters in width on steep slopes (greater than 25 degrees) that form and incrementally grow in late spring to summer, then fade or disappear in fall. They reform at nearly the same locations in multiple Mars years, extending down-slope from bedrock outcrops or rocky areas, and are often associated with small channels on equator-facing slopes in the southern hemisphere. The streaks grow in temperatures at which brines (waters that have high concentrations of dissolved minerals, largely salts) would be liquid. The exact mechanism of the streak activity is not completely understood, but brines are the best explanation to date. MRO is also updating its software to prepare for supporting the MSL/Curiosity entry/descent/landing and surface operations.

## 2003 MARS EXPLORATION ROVER

2003 Mars Exploration Rover Opportunity's study of sulfate-rich sands at Eagle and Endurance Craters revealed evidence of playa lakes that repeatedly formed and evaporated. The sands were subsequently reworked by water and wind, solidified into rock, and soaked by groundwater. Opportunity examined more sedimentary bedrock exposures on its way from Endurance to Victoria Crater, and explored the area around Victoria Crater for two years. Opportunity's measurements indicated that the environmental conditions responsible for the rocks previously studied in Meridiani Planum pervaded a wide, regional area. Fragments of the meteorite that may have excavated the crater were also found. In August 2011, after a 19 kilometer (12 mile) journey, Opportunity achieved a significant milestone by arriving at Endeavour Crater, where the compositions of rocks vary in age from recent to ancient. Rocks in the area show evidence of chemical reactions with liquid water and will help elucidate the environmental conditions of the earlier history of Mars. In addition, these rocks show for the first time the formation within the volcanic bedrock of the mineral gypsum, which precipitated in water and may indicate conditions hospitable for life.

## 2001 MARS ODYSSEY

2001 Mars Odyssey has become the longest-lived Martian spacecraft in history (more than 10 years). Odyssey's longevity enables continued science, including the monitoring of seasonal changes on Mars from year to year and the most detailed full-globe maps ever made of the planet. Odyssey also continues to serve as the primary communication relay for the MER Opportunity, and will be a key communications link for MSL.

# OUTER PLANETS

## FY 2013 BUDGET

| Budget Authority (in $ millions) | Actual FY 2011 | Estimate FY 2012 | FY 2013 | Notional FY 2014 | FY 2015 | FY 2016 | FY 2017 |
|---|---|---|---|---|---|---|---|
| **FY 2013 President's Budget Request** | **91.9** | **122.1** | **84.0** | **80.8** | **78.8** | **76.2** | **76.3** |
| Change From FY 2012 Estimate | -- | -- | **-38.1** | | | | |
| Percent Change From FY 2012 Estimate | -- | -- | **-31.2%** | | | | |

**Cassini completed its initial four-year mission to explore the Saturn System in June 2008 and the first extended mission, called Cassini Equinox, in July 2010. The healthy spacecraft is now seeking to make exciting new discoveries in a second extended mission called Cassini Solstice. The mission extension, which goes through September 2017, is named for the Saturnian summer solstice occurring in May 2017.**

The Outer Planets program consists of three strategic elements: the ongoing Cassini mission to Saturn; Supporting Research and Technology (SR&T); and a pre-formulation study effort for a potential future outer planets mission. These elements enable science investigations across a broader array of disciplines and in more depth than smaller, tightly focused competed missions. The science discoveries made by these strategic missions are significant and provide answers to long-held questions and theories about the origin and evolution of outer planets.

## EXPLANATION OF MAJOR CHANGES FOR FY 2013

None.

## ACHIEVEMENTS IN FY 2011

Cassini captured the first-ever, up-close images and sounds of a Saturn thunderstorm that extended over eight times the entire size of Earth. The storm was about 500 times larger than the biggest storm previously seen by Cassini during several months from 2009 to 2010. Scientists studied the sounds of the new storm's lightning strikes and analyzed images taken between December 2010 and February 2011. Data from Cassini's radio and plasma wave science instrument showed the lightning flash rate as much as ten times more frequent than during other storms monitored since Cassini's arrival to Saturn in 2004. The origin of these storms is unknown, and has never been seen a storm of this magnitude on Saturn before.

Cassini also captured the icy face and spectacular water plumes of Saturn's moon Enceladus during its successful flyby on Nov. 6, 2011. During this Enceladus encounter, the 16th of Cassini's mission, the spacecraft passed the moon at distance of about 300 miles (500 kilometers). The most intense plumes were seen coming from long cracks in the ice that line up in the direction of Saturn indicating that stress plays a major role in producing these water plumes or geysers.

## KEY ACHIEVEMENTS PLANNED FOR FY 2013

The Uranus study initiated in FY 2012 will be completed and the delivered to NASA. In addition, the Enceladus study will be initiated as described in the planetary decadal study.

## BUDGET EXPLANATION

The FY 2013 request is $84.0 million. This represents a $38.1 million decrease from the FY 2012 estimate ($122.1 million).

The decrease in the funding for Outer Planets program in the outyears is due to the completion of three major mission architecture studies solely on Europa. Study funding will be needed for initiating a study on the third highest rated flagship, a mission to Uranus and a study on Enceladus.

# Non-Operating Missions

## OUTER PLANETS FLAGSHIP

In FY 2013, the Outer Planets Flagship mission will study and initiate technology improvements as necessary for future Outer Planets missions such as radiation tolerance of science instruments, lower mass and power spacecraft design, and precision landing for in situ exploration. Two preliminary studies will also be initiated for a Uranus orbiter and probe, and an Enceladus orbiter. The objectives of the Uranus mission will include inserting an orbiter into Uranus orbit to study the atmosphere, rings, magnetic field, magnetosphere, and noble gas abundances of Uranus, as well as deploying a small atmospheric in situ probe to conduct a tour of the larger satellites. The mission will also seek to answer long-standing questions about Uranus regarding its lack of heat radiation like other gas giants in our solar system, the origin and reason for its apparent tilted axis, and the seasonal weather patterns of Uranus. The primary objectives of the Enceladus orbiter will include determining the nature and source of its remarkably active cryovolcanic activity, and the internal structure and chemistry of Enceladus. The mission would also attempt to determine how Enceladus interacts with the rest of the Saturnian system, characterize the surface for future landing sites, and the nature of the surfaces and interiors of Rhea, Dione, and Tethys.

## OUTER PLANETS RESEARCH

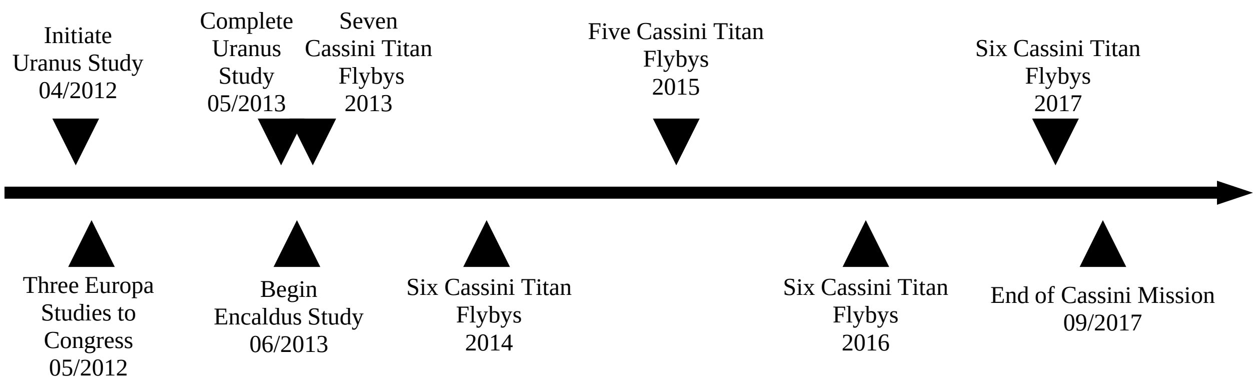
Outer Planets Research increases the scientific return of NASA outer planets missions and guides current mission operations (e.g., selecting Cassini imaging targets) as well as future mission planning (e.g., mission concept studies for Titan missions). The competitive programs within Outer Planets Research effort increase understanding of the origin and evolution of the outer solar system and broadens the science community's participation in the analysis of data returned by Cassini, Galileo, and other missions.

## Operating Missions

### CASSINI

Cassini, in its extended operations phase, is a flagship mission in orbit around Saturn that has profoundly altered our understanding of the planet, its famous rings, magnetosphere, icy satellites, and particularly the moons, Titan and Enceladus. It was launched in October 1997 and arrived at Saturn in July 2004 in order to explore the Saturn system in detail, including its rings and moons. A major focus is Saturn's largest moon, Titan, with its dense atmosphere, methane-based meteorology, and geologically active surface. Cassini completed its prime mission in July 2008, completed its Equinox extended mission in July 2010, and began the Solstice extended mission in October 2010. The Solstice mission will observe seasonal and temporal change in the Saturn system, especially at Titan, to understand underlying processes, and prepare for future missions. The Solstice mission will continue to operate and conduct data analysis through March 2018. The Solstice mission enables another 155 revolutions around the planet, 54 flybys of Titan and 11 flybys of Enceladus. In 2017, an encounter with Titan will change its orbit in such a way that, at closest approach to Saturn, it will be only 3,000 km above the planet's cloud tops, and below the inner edge of the D ring. This sequence of "proximal orbits" will end when another encounter with Titan will send the Cassini probe into Saturn's atmosphere.

## Project Schedule



# OUTER PLANETS

## Program Management & Commitments

Management responsibility for Cassini, and for pre-formulation of the Outer Planets future mission concept development, resides at JPL. Scientific mission priorities for the program and the research efforts reside within SMD/Planetary Science Division.

The Cassini mission is a cooperative project of NASA, the ESA and the Italian Space Agency. JPL manages the mission. The Cassini orbiter and its two onboard cameras were designed, developed and assembled at JPL.

Cassini is committed to continue delivery of science data until 2018, contingent upon health and status of the spacecraft. Outer Planets Research is included in the annual ROSES NRA.

| Project/Element | Provider |
|---|---|
| Outer Planets Flagship (Pre-Project Formulation) | Provider: JPL<br>Project Management: JPL<br>NASA Center: JPL<br>Cost Share: None |
| Outer Planets Research | Provider: HQ<br>Project Management:<br>NASA Center: Multiple<br>Cost Share: None |
| Cassini | Provider: JPL<br>Project Management: JPL<br>NASA Center: JPL<br>Cost Share: The Italian Space Agency provided Cassini's high-gain communication antenna and the Huygens probe was built by ESA. |

## Acquisition Strategy

All major acquisitions contracts for Cassini are in place. As a result of the planetary decadal survey, the Outer Planets program will continue to conduct studies for a future flagship mission opportunity within the existing funding horizon.

# OUTER PLANETS

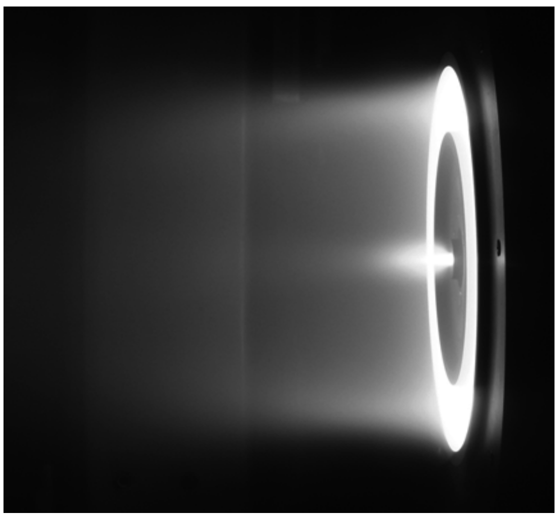
## INDEPENDENT REVIEWS

| Review Type | Performer | Last Review | Purpose/Outcome | Next Review |
|---|---|---|---|---|
| Quality | Senior Review Panel | Feb-09 | Cassini senior review for the Solstice extended mission recommended approval of the extended mission science. | Feb-12 |

# TECHNOLOGY

## FY 2013 BUDGET

| | Actual | Estimate | | Notional | | | |
|---|---|---|---|---|---|---|---|
| **Budget Authority (in $ millions)** | **FY 2011** | **FY 2012** | **FY 2013** | **FY 2014** | **FY 2015** | **FY 2016** | **FY 2017** |
| **FY 2013 President's Budget Request** | **117.3** | **144.9** | **132.9** | **84.6** | **85.9** | **90.9** | **99.6** |
| Change From FY 2012 Estimate | -- | -- | **-12.0** | | | | |
| Percent Change From FY 2012 Estimate | -- | -- | **-8.3%** | | | | |



**NEXT (NASA's Evolutionary Xenon Thruster) could revolutionize the way we send science missions deeper into the solar system. NEXT will have a significant increase in power, efficiency and system performance characteristics compared to the Deep Space 1 ion thruster. Modern Hall thrusters are capable of propelling a spacecraft up to about 112,000 miles per hour, compared to the Space Shuttle's top speed of around 18,000 miles per hour. The tradeoff for the spacecraft to reach this high top speed is low acceleration over a long time.**

Planetary Science missions demand advances in both power and propulsion systems to enable successful trips to harsh environments, far from the Sun, with highly challenging trajectories and operations. To meet these needs, the Planetary Science Technology program includes the In-Space Propulsion (ISP), Radioisotope Power Systems (RPS), and Advanced Multi-Mission Operations System (AMMOS) projects. The ISP project develops in-space propulsion technologies that can enable or benefit near- and midterm NASA missions. These technologies will enhance the performance of planetary science missions by allowing increased science payload mass, reduced launch costs, and decreased mission trip times. The RPS project advances the capabilities of spacecraft power systems, thereby making it possible for missions to travel to destinations distant from the sun, or where sunlight is obscured or infrequent. RPS is developing flight Advanced Stirling Radioisotope Generators (ASRG) for the 2014 time frame. AMMOS provides planetary science missions with a set of operations, navigation and design software tools and services for flight mission training, mission operations, space communications resources allocation, and improved space communication.

The budget for restarting the Nation's plutonium production capacity is included in the program. Managed in close cooperation with OCT, these technology investments focus on the unique needs of robotic planetary missions, and leverage Agency cross-cutting efforts in space propulsion, power, and automation/operations technologies.

# TECHNOLOGY

## EXPLANATION OF MAJOR CHANGES FOR FY 2013

No program changes.

## ACHIEVEMENTS IN FY 2011

ISP completed the electric propulsion Hall thruster development task in FY 2011. The NASA Evolutionary Xenon Thruster (NEXT) completed a long duration test, demonstrating a 600 kg Earth return payload capability. Down-select and propulsion system component development was completed for the Mars Ascent Vehicle. Aerocapture transitioned to a flight validation mission. Preliminary development of a light weight tank was completed for Sample Return Propulsion.

## KEY ACHIEVEMENTS PLANNED FOR FY 2013

The ISP will continue toward completion of the NEXT electric propulsion life validation, and will initiate technology study and feasibility on the Mars Ascent Vehicle.

## BUDGET EXPLANATION

The FY 2013 request is $132.9 million. This represents a $12.0 million decrease from the FY 2012 estimate ($144.9 million).

Although overall program funding from FY 2012 to FY 2013 is less, the current budget reflects an increase in RPS to complete the development of an ASRG in order to demonstrate an improved capability over the utilization of Multi-Mission Radioisotope Thermoelectric Generator technology.

# Projects

## IN-SPACE PROPULSION (ISP)

ISP will enable access to more challenging and interesting science destinations, including sample return missions. ISP continues to advance several propulsion technologies in support of future Flagship, Discovery, Mars, and New Frontiers missions. ISP invests in high-priority technology areas such as the electric propulsion and aerocapture/Earth entry, descent, and landing technologies identified in the Planetary Decadal survey. ISP will continue increasing its emphasis on sample return propulsion technology development. The foci will be: completing Earth Entry Vehicle heat shield micrometeoroid/orbital debris characteristics studies, a preliminary design of a Multi-Mission Earth Entry Vehicle concept and continuing this technology development; and initiating thruster long-duration testing and continuing other subsystem technology developments for the High Voltage Hall Accelerator thruster technology applicable to Earth Return Vehicles, transfer stages, and low-cost electric propulsion systems for Discovery-class missions. The ISP project is responsive to the Planetary 2011 decadal survey.

# TECHNOLOGY

RPS continues low-level investments in advanced Stirling, thermoelectric conversion, and thermal photovoltaic technologies in response to mission needs identified by the planetary decadal survey.

## RADIOISOTOPE POWER SYSTEMS (RPS)

The RPS program was chartered for implementation on March 24, 2011. The RPS program is focused on the development of radioisotope power capabilities to enable NASA solar system exploration, the first of which is the Advanced Stirling Radioisotope Generator (ASRG). The RPS program also funds cross-cutting multi-mission activities to keep the development, implementation, and approval of radioisotope power systems off the critical path for future RPS missions. This work includes the National Environmental Policy Act (NEPA) process development, multi-mission launch vehicle data book development, safety analysis and testing, and radiological contingency response process improvement. All of this work is critical to facilitate the application of RPS. RPS is structured to manage both the technology investments and systems development, such as the development and testing of the ASRG. The program transitions acquisition of flight units to a mission-specific user. The program also assumes responsibility for performing RPS mission studies, sustaining needed RPS capabilities, and providing crosscutting launch approval activities. However, funds are not included within the RPS budget for the procurement of nuclear material required to support missions in formulation.

In FY 2013, RPS will complete an extended performance testing of the Advanced Stirling Radioisotope Generator (ASRG) engineering unit, and complete the development of a flight qualification unit to enable delivery of one ASRG flight unit for the 2016-2017 Discovery flight opportunity. RPS will continue the development of advanced radioisotope thermoelectric generator couples by validating lifetime and four-couple module power. RPS will also fund DoE safety testing to verify safety models for solid upper stages.

## ADVANCED MULTI-MISSION OPERATION SYSTEM (AMMOS)

AMMOS provides multi-mission operations, navigation, design, and training tools for Planetary Science flight missions, and invests in improved communications and navigation technologies. The AMMOS project will continue to provide and develop multi-mission software tools for spacecraft navigation and mission planning throughout FY 2013. In addition, AMMOS will pursue complimentary collaborations with the Agency's cross-cutting Space Technology program.

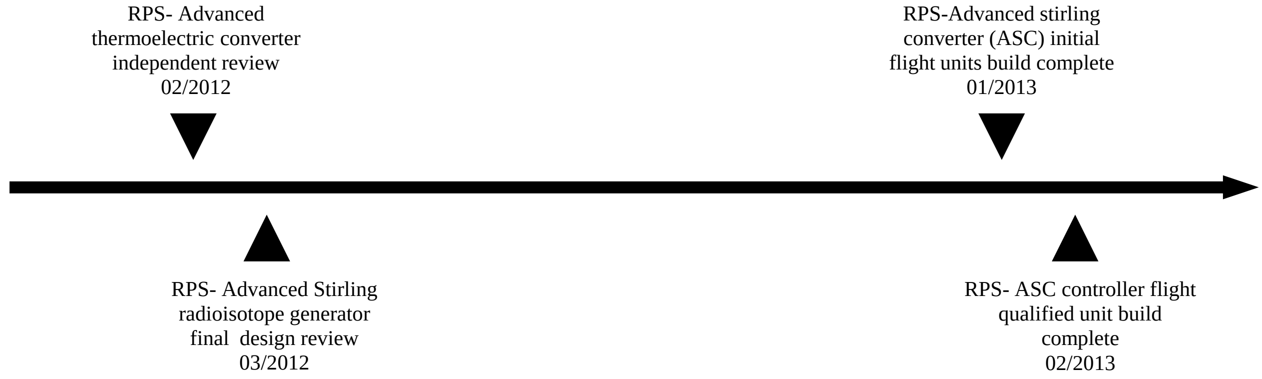
## PLUTONIUM

NASA and DoE have initiated project planning and activities for implementing a Plutonium (Pu-238) production restart. NASA continues to work with DOE to assess the need and schedule for plutonium supplies to respond to the diminishing inventory of Pu-238 available to NASA missions from past U.S. production and material purchased from Russia. DoE continues to negotiate with Russia to re-establish a contract in which the United States would purchase Pu-238. In 2009, the Russian government cancelled the contract for purchasing the remaining material that they had agreed to sell to the United States. Meanwhile, studies of the Planetary decadal survey mission set, conducted by the RPS program have

# TECHNOLOGY

revalidated the need for Pu-238 production to support NASA missions, as current inventory will be exhausted by scheduled missions within the next decade.

## Program Schedule




## Program Management & Commitments

SMD provides overall oversight of the Technology program. GRC is responsible for the ISP and RPS projects. JPL is responsible for the AMMOS project.

In FY 2013, the ISP program will continue long-duration tests for the Hi/HAC Engineering Model (EM) Thruster and NEXT. The goal of NEXT is to achieve 750 kilograms of Xenon throughput. (Based on an initial set of design reference missions, the original throughput design point for NEXT was 300 kilograms, with a 1.5 times demonstration validation requirement of 450 kilograms. By demonstrating >750 kilograms throughput, the qualified design point for the NEXT thruster can be set at 500 kilograms, which matches the maximum throughput requirement seen in recent mission studies.)

# TECHNOLOGY

| Project/Element | Provider |
|---|---|
| ISP | Provider: GRC<br>Project Management: GRC<br>NASA Center: GRC, MSFC, JPL, LaRC, ARC, GSFC<br>Cost Share: None |
| RPS | Provider: GRC<br>Project Management: GRC<br>NASA Center: GRC, JPL, KSC<br>Cost Share: Department of Energy |
| AMMOS | Provider: JPL<br>Project Management: JPL<br>NASA Center: JPL<br>Cost Share: None |
| Plutonium | Provider: Department of Energy<br>Project Management: HQ<br>NASA Center: GRC<br>Cost Share: None |

## Acquisition Strategy

Technology activities are solicited using NASA ROSES NRA, and selections are made using a competitive, peer-reviewed process. DoE completed an acquisition for ASRG flight system development: Lockheed Martin for RPS. JPL provides management and the navigation and space communication software tools.

# TECHNOLOGY

## MAJOR CONTRACTS/AWARDS

| Element | Vendor | Location |
|---|---|---|
| Advanced Stirling Radioisotope Generator (ASRG) | Department of Energy<br><br>Lockheed Martin | Idaho National Laboratory, Los Alamos National Lab, Oak Ridge National Lab<br><br>Denver, CO |
| Mars Ascent Vehicle | ATK<br>Lockheed Martin<br>Northrop Grumman | Elkton, MD<br>Denver, CO<br>Los Angeles, CA |

## INDEPENDENT REVIEWS

| Review Type | Performer | Last Review | Purpose/Outcome | Next Review |
|---|---|---|---|---|
| Relevance | National Academies | Dec-10 | Assessing the restart and sustainment of domestic production of radioisotope heat source material for deep space and other exploration missions. Assessing the development of and standards for flight certification of ASRG for flagship and other missions. | TBD |
| Performance | SRB/IPAO | Sep-10 | Program Implementation Review. Based on the program readiness and SRB recommendation, subsequent Agency approval was granted to the RPS program on December 9, 2010, by the Agency Program Management Council. | Sep-12 |